FEBRUARY 1953

Journal

VOL. 45 • NO. 2

AMERICAN WATER WORKS ASSOCIATION

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Pump Selection	Niles
Specifications for Centrifugally Cast Iron Pipe	ASA A21.6, A21.8

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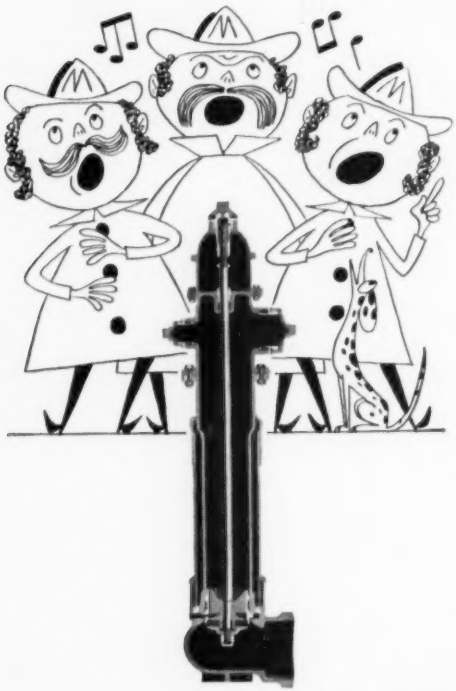

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150th anniversary

Journal

AMERICAN WATER WORKS ASSOCIATION

February 1953

Vol. 45 • No. 2

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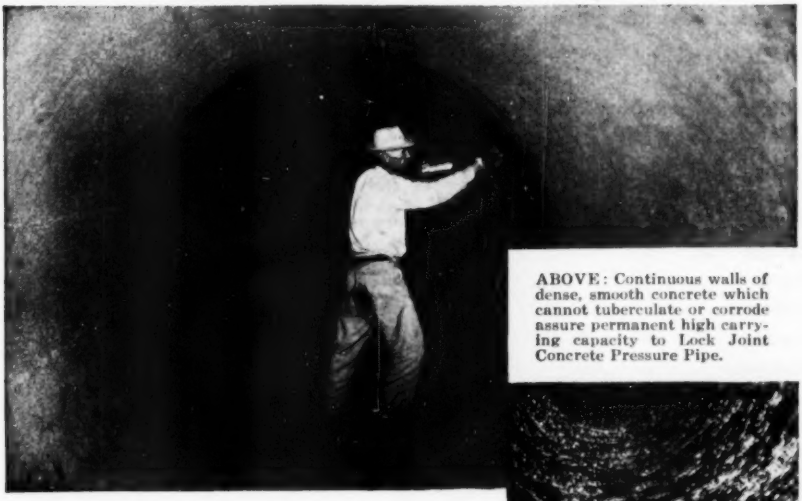

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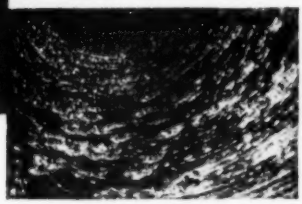

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Research designed it for lasting strength

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AWWA SECTIONS

Feb. 11–13—Indiana Section at Lincoln Hotel, Indianapolis. Secretary, G. G. Fassnacht, State Dept. of Health, 1330 W. Michigan St., Indianapolis 7, Ind.

Feb. 17—New Jersey Section Winter Luncheon, Essex House, Newark. Secretary, C. B. Tygert, Wallace & Tiernan Co., Inc., Box 178, Newark 1, N.J.

Mar. 18–20—Illinois Section at LaSalle Hotel, Chicago. Secretary, J. Leslie Hart, Western Sales Manager, U.S. Pipe & Foundry Co., 122 S. Michigan Ave., Chicago 3, Ill.

Mar. 19—New England Section at Statler Hotel, Boston. Secretary, George G. Bogren, Partner, Weston & Sampson, 14 Beacon St., Boston 8, Mass.

Mar. 23–25—Southeastern Section at Dempsey Hotel, Macon, Ga. Secretary, T. A. Kolb, 89 Alexander St., Charleston, S.C.

Apr. 6–8—Canadian Section at Statler Hotel, Buffalo, N.Y. Secretary, A. E. Berry, Director, Ontario Dept. of Health, Parliament Bldgs., Toronto 8, Ont.

Apr. 16–17—Nebraska Section at Cornhusker Hotel, Lincoln. Secretary, E. Bruce Meier, Asst. Prof. of Civ. Eng., Univ. of Nebraska, Lincoln, Neb.

Apr. 16–17—New York Section at Mark Twain Hotel, Elmira. Secretary, R. K. Blanchard, Vice-Pres. & Engr., Neptune Meter Co., 50 W. 50th St., New York 20, N.Y.

Apr. 16–18—Pacific Northwest Section at Multnomah Hotel, Portland, Ore. Secretary, O. P. Newman, Exec. Vice-Pres., Boise Water Corp., Boise, Idaho.

Apr. 16–18—Arizona Section at San Marcos Hotel, Chandler. Secretary, M. V. Ellis, Supervisor, Sewage Treatment Plant, Phoenix, Ariz.

AWWA ANNUAL CONFERENCE

Grand Rapids, Mich. May 10–15, 1953

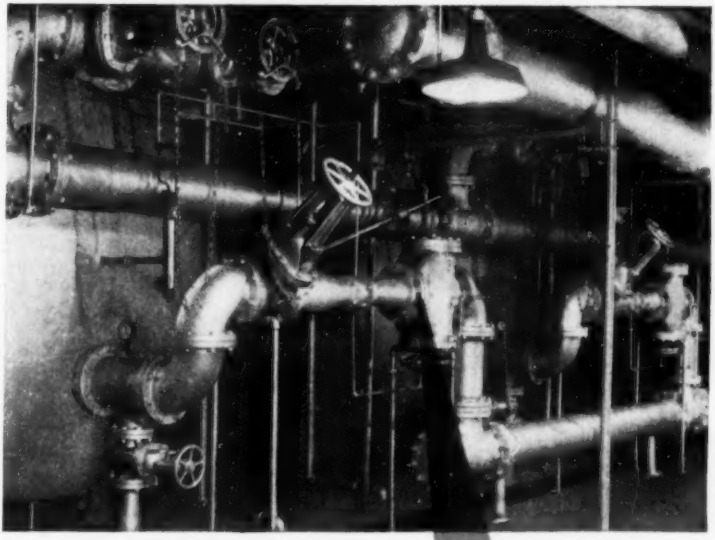
All reservations will be cleared through the AWWA office. The hotels have agreed to accept no reservations for the 1953 Conference except as they are requested on the standard form, through the AWWA.

(Continued on page 12)

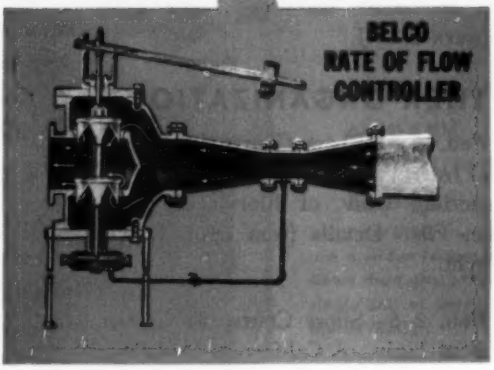
PROCESSES FOR REMOVAL OF WATER IMPURITIES

BELCO horizontal filters provide low cost treated water

INCORPORATE AUTOMATIC BELCO RATE OF FLOW CONTROLLERS FOR OPTIMUM CONTROL



Belco provides automatic or manual filtration equipment for any flow capacity. The experience of Belco engineers in process control is unmatched. The Belco Rate of Flow Controller insures constant rate of flow under varying pressure conditions. The unit is sensitive, accurate and designed for low head loss. More information? Ask the Belco man!



★ We invite your consultation regarding all water conditioning requirements. Get acquainted with our organization for authoritative assistance and close cooperation. Write for late descriptive bulletins.

Belco

Belco Industrial Equipment Division, Inc.

PATERSON 3, NEW JERSEY

Coming Meetings

(Continued from page 10)

Apr. 22–24—Kansas Section at Broadview Hotel, Wichita. Secretary, Harry W. Badley, Repr., Neptune Meter Co., 119 W. Cloud, Salina, Kan.

Apr. 24–25—Montana Section at Kalispell Hotel, Kalispell. Secretary, Arthur W. Clarkson, Asst. Director, Div. of San. Eng., State Board of Health, Helena, Mont.

June 17–19—Pennsylvania Section at Hershey Hotel, Hershey. Secretary, L. S. Morgan, Div. Engr., State Dept. of Health, Greensburg, Pa.

June 17—New Jersey Section Summer Outing and Inspection of Johns-Manville Research Center, Finderne. Luncheon at Martinsville Inn, Martinsville. Secretary, C. B. Tygert, Wallace & Tiernan Co., Inc., Box 178, Newark 1, N.J.

OTHER ORGANIZATIONS

Feb. 2–4—Short Course in Industrial Instrumentation at College of Engineering, Univ. of Florida, Gainesville, Fla. Details from Prof. R. C. Specht.

Feb. 2–6—Short Course in Corrosion at Univ. of California, Berkeley, Calif., in cooperation with National Assn. of Corrosion Engineers. Details from University Extension.

Feb. 17–19—American Concrete Inst. at Statler Hotel, Boston, Mass. Details from institute, 18263 W. McNichols Rd., Detroit 19, Mich.

Feb. 19–20—Ohio Water Clinic at Ohio State Univ., Columbus 10, Ohio. Details from Kenneth W. Cosens, Assoc. Prof. of Civil Engineering.

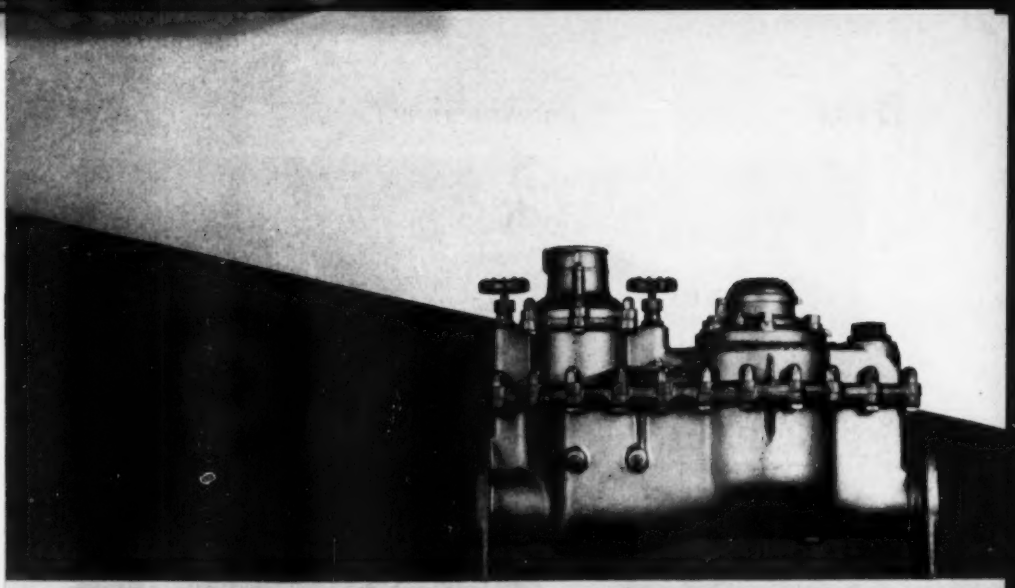
Mar. 16–20—National Assn. of Corrosion Engineers at Chicago, Ill. Details from A. B. Campbell, Executive Secy., 1061 M & M Bldg., Houston 2, Tex.

Mar. 18–20—Short course for water and sewerage personnel at Louisiana State Univ., Baton Rouge. Details from John H. O'Neill, Director, Div. of Public Health Eng., State Dept. of Health, Civil Courts Bldg., New Orleans 7, La.

Mar. 23–27—Western Metal Exposition and Congress, Statler Hotel, Los Angeles, Calif. Details from William H. Eisenman, Secy., American Society for Metals, 7619 Beverly Blvd., Los Angeles, Calif.

Apr. 6–30—Lectures on prestressed concrete, Monday and Thursday evenings at Newark College of Engineering, 367 High St., Newark 2, N.J. Details from Special Courses Div.

Apr. 20–21—Industrial waste disposal regional conference at New Orleans, La. Details from H. M. Conway Jr., Director, Southern Assn. of Science & Industry, 5009 Peachtree Rd., Atlanta, Ga.



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HERSEY COMPOUND METERS

will accurately measure a wider range of flows than any other single unit or assembly of meters.

A Hersey Creation that has never been equaled

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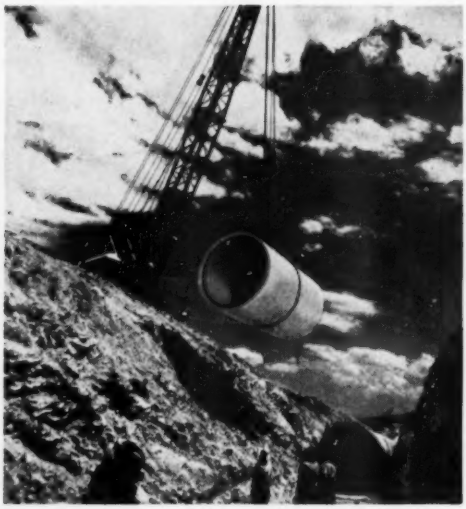
Denver Prefers Concrete Pressure Pipe



Thirty-two years ago the city of Denver installed its first concrete pressure pipe. From time to time, as demands for water increased, Denver added to its water transmission system . . . and the pipe selected most has been concrete pressure pipe.

Reasons for this preference are: (1) permanent high carrying capacity, (2) immunity to blow-out or rupture, (3) proof against tuberculation, corrosion, and electrolytic damage, (4) extremely long life and maintenance economy.

The performance in Denver and in other cities, large and small, proves the distinct advantages offered by concrete pressure pipe. Let us show you how these same advantages can be used for the water system in your community.

Engineering Assistance is offered, without obligation, on any water storage or transmission problem. Write Mr. H. F. Peckworth, Managing Director, American Concrete Pressure Pipe Association.

Water for Generations to come

Concrete PRESSURE Pipe

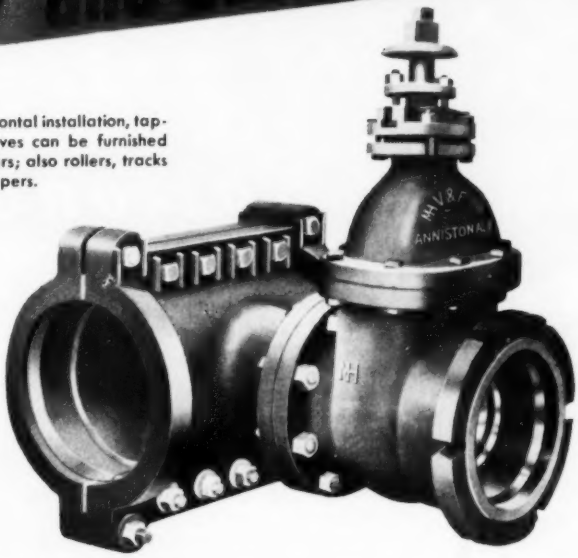
AMERICAN CONCRETE PRESSURE PIPE ASSOCIATION
228 North LaSalle Street
Chicago 1, Illinois

FOR TAPPING MAIN UNDER PRESSURE

TAPPING VALVE and SLEEVE

MH

For horizontal installation, tapping valves can be furnished with gears; also rollers, tracks and scrapers.



A. W. W. A.—CLASS C

Designed for tapping a main under pressure to take off a branch larger than corporation cock size. Flange on one side of valve bolts to sleeve; other side of valve may be hub or mechanical joint connection, either of which has special flange cast integral for attaching any standard make tapping machine. Can be furnished with rising stem for use in manhole or valve pit. Features of M & H sleeves are strong, heavy design and liberal length.

M & H Tapping Valve meets specification of A. W. W. A. Class C and Tapping Sleeve is Manufacturer's Standard. For complete information, write or wire M & H VALVE AND FITTINGS COMPANY, Anniston, Alabama.

M&H PRODUCTS FOR WATER WORKS • FILTER PLANTS INDUSTRY • SEWAGE DISPOSAL AND FIRE PROTECTION

When pipe efficiency drops you need... **National**

When pumping costs rise, pressures fall and capacity is way down—
You need *National* cleaning!

Often, lines assumed to be in top operating condition are actually delivering less than half of their rated capacity. For instance—a tuberculated 48" pipe, having a co-efficient of 93 can carry no more water than a clean 42" pipe. Think how much difference this makes in costs when it must be compensated for by either greater power consumption at the pumping station or by larger mains in the ground.

Remember, the National Water Main Cleaning Company *guarantees* to restore any water main to 95% of its original carrying capacity.

There's no obligation when National's engineers inspect and estimate cleaning costs of your mains, so write or phone today!

NATIONAL WATER MAIN CLEANING COMPANY
50 Church Street • New York, N. Y.

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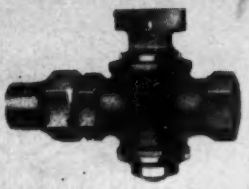
ATLANTA, GA; 333 Candler Building • BERKELEY, CALIF; 905 Grayson Street • DECATUR, GA; P. O. Box 385 • BOSTON, MASS; 115 Peterboro Street • CHICAGO; 122 So. Michigan Avenue • ERIE, PA; 439 E. 6th Street • FLANDREAU, S.D; 315 N. Crescent Street • KANSAS CITY, MO; 406 Merchandise Mart and 2201 Grand Avenue • LITTLE FALLS, N.J; BOX 91 • LOS ANGELES; 5075 Santa Fe Avenue • MINNEAPOLIS, MINN; 200 Lumber Exchange Building • OMAHA, NEBR; 3812 Castellar Street • RICHMOND, VA; 210 E. Franklin Street • SALT LAKE CITY; 149–151 W. Second South Street • SIGNAL MOUNTAIN, TENNESSEE; 204 Slayton Street • DALLAS, TEXAS; 6617 Snider Plaza • MONTREAL, CANADA; 2028 Union Avenue • WINNIPEG, CANADA; 576 Wall Street • HAVANA, CUBA; Lawrence H. Daniels, P. O. Box 531 • SAN JUAN, PUERTO RICO; Luis F. Caratini, Apartado 2184.

A PERFECT TEAM . . .

HAYS®

CORPORATION and CURB STOPS



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A complete line of Water Works products . . . Conforms to all AWWA Standards . . . Quality that comes from over 80 years' manufacturing experience . . . Fittings interchangeable with other makes . . . Corporation stops can be installed with any standard tapping machine equipment.

HAYS

Water Works Products

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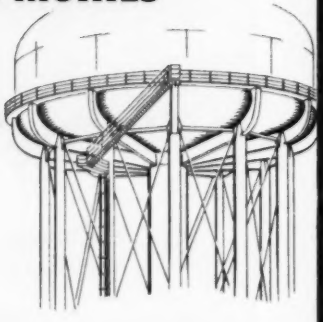
—a million gallon

RADIAL CONE

ELEVATED STEEL TANK

by PITTSBURGH • DES MOINES



The *Radial Cone* design is particularly applicable for elevated tanks of medium to large capacity where *low head range* is an important consideration. • Write for a discussion of the Pittsburgh-Des Moines elevated tank type best meeting *your* requirements.

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CHICAGO (3), 1228 First National Bank Bldg.	SEATTLE . . . . . 532 Lane Street
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for every water meter service

Badger makes the meters you need . . . any type, any size, for any water-measuring job in home or industrial service: 5/8" to 1 1/4" home service meters; 2" to 12" Turbine (Current) Meters; 2" to 10" compound meters and industrial meters . . . of many sizes and types . . . also time-and-money saving accessories vital to efficient installation and servicing, including famous Badger Meter Testing Machines. For complete meter service, it pays to contact Badger.

"MEASURING THE WATER OF THE WORLD"

First for Accuracy • Low-Cost Maintenance • Durability • Sensitivity

BADGER *Water* METERS

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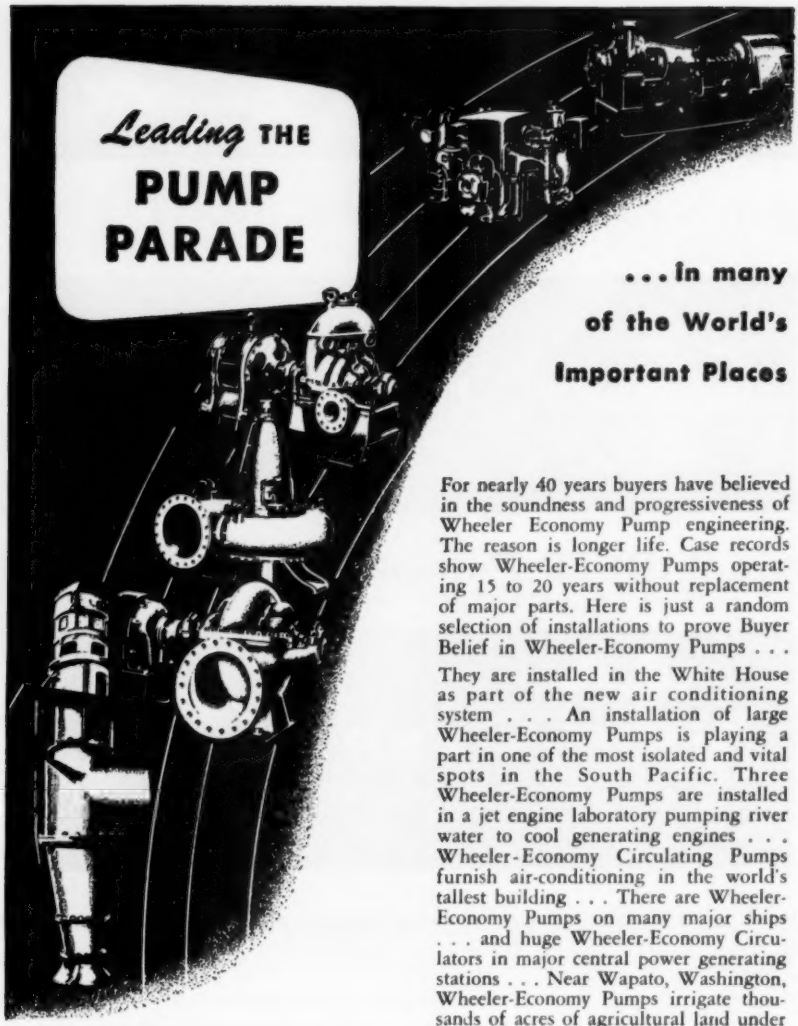

. . . In many of the World's Important Places

For nearly 40 years buyers have believed in the soundness and progressiveness of Wheeler Economy Pump engineering. The reason is longer life. Case records show Wheeler-Economy Pumps operating 15 to 20 years without replacement of major parts. Here is just a random selection of installations to prove Buyer Belief in Wheeler-Economy Pumps . . .

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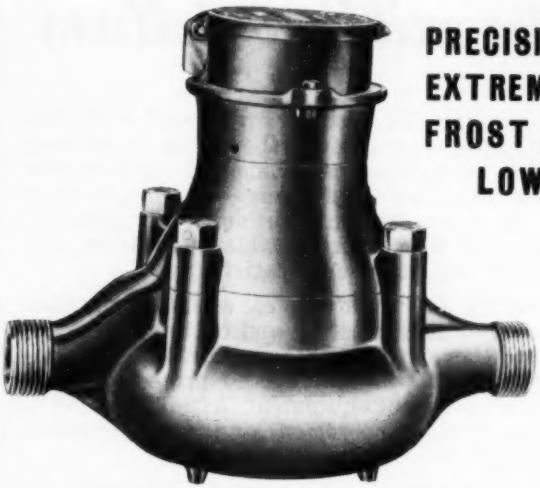
19TH AND LEHIGH, PHILADELPHIA 32, PA.

CALMET



PRECISION ACCURACY
EXTREME LONG LIFE
FROST PROTECTED
LOW UPKEEP

WILL MEASURE UP TO YOUR REQUIREMENTS

PRECISION ACCURACY—CALMET's oscillating piston is semi-floating, precision balanced. A super-sensitive meter that measures with unfailing accuracy the various flows to the smallest drip.

EXTREME LONG LIFE—CALMET's slower moving piston and gear train ratio of 256-to-1 assures long life, less wear on precision parts. Simple design assures years of service with a minimum of attention.

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FROST PROTECTED—Exclusive FROST-PROOF BOLTS provide maximum protection against damage from freezing or excessive pressure, by allowing the main case and the measuring chamber to separate. The meter can then be serviced at the cost of only a few cents for shear pins.

● ***SALES REPRESENTATIVES—Write for complete details of the CALMET franchise in your territory.***

CALMET WATER METERS

MADE BY WELL MACHINERY & SUPPLY CO., INC.—FORT WORTH, TEXAS

how to save... a quarter million dollars

A large mid-western city recently was faced with this problem. Within eight years after the water treatment plant was placed in operation, the submerged steel showed active corrosion of alarming proportions — the warning of a possible loss of a quarter million dollar investment. Various coatings were tested for possible application, but none of those tested was considered satisfactory.

It was then that the ERP man was called in. At approximately half the cost of sand blasting and coating, and with no surface preparation or long outage time, an ERP cathodic protection system was installed to protect all submerged steel in the treatment equipment. After three years *there has been no further corrosion, and an appreciable saving in maintenance has been realized!*

This is a typical example of ERP at work. Whether your corrosion problem involves a tank, basin, deep well, water works treatment structure, or pipe line it will be worth your while to discuss it with your ERP man. His expert advice may save you *dollars* tomorrow.

COMPLETE CATHODIC PROTECTION SERVICE • DESIGN ENGINEERING MAINTENANCE INSTALLATION EQUIPMENT

ELECTRO RUST-PROOFING CORP. (N. J.)

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Represented in Principal Cities in the United States

Over 15 years of cathodic protection engineering, research and development

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IS *YOUR* WATER-SOFTENING SYSTEM SLUGGISH?

It is, unless your exchanger

. . . Has capacity up to 30,000 grains of hardness per cubic foot, even at peak flow rates of 10 gal./sq. ft./min.

. . . Thrives on a salt-starvation diet of as little as ¼ pound per 1,000 grains of hardness removed.

. . . Gives years of trouble-free service without attrition losses — can be operated safely over the entire pH range and at high temperatures — is stable to low silica-content water, acid, alkali, and oxidizing and reducing agents.

AMBERLITE IR-120 Resin Exchange meets all these efficiency tests. A typical AMBERLITE unit has delivered almost 5,000,000 gallons of softened water per cubic foot of resin without capacity or attrition losses; and it's still in operation.

Ask your water-treating equipment supplier or your consulting engineer about AMBERLITE IR-120 — as the exchanger in a new softening installation, or as a replacement for siliceous exchanger. Meanwhile, write Dept. W-1 for full technical data.

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ROHM & HAAS COMPANY

THE RESINOUS PRODUCTS DIVISION

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AMBERLITE *is a trademark, Reg. U. S. Pat. Off. and in principal foreign countries.*

● It isn't necessary to specify over-sized pipe for your large-diameter water lines to meet anticipated "shrinkage" in flow capacity due to tuberculation.

It's far less expensive to *prevent tuberculation* by coating the pipe interior with a smooth, spun lining of Bitumastic® 70-B Enamel. Then you can select pipe size solely on the basis of desired capacity.

Bitumastic gives you a lastingly-high coefficient of flow that reduces pumping costs . . . results in savings that more than pay the cost of the lining.

Bitumastic 70-B Enamel also makes it unnecessary for you to specify additional wall thickness to compensate for corrosion. An exterior coating of Bitumastic 70-B Enamel, combined with the spun lining, forms a barrier against all types of corrosion, inside the pipe and out.

Make certain your community is getting its money's worth of proper protection—specify Bitumastic 70-B Enamel for your large-diameter lines.

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FOR SAFER CONTROL ---------- OF HARD-TO-HANDLE FLUIDS

CRANE Packless Diaphragm Valves

Now Available in *New* Materials

WORKING PRESSURES—up to 150 pounds. Water, air, oil, or gas, 180° F. maximum temperature, depending on valve size and materials.

You asked for it—and now Crane gives you this outstanding Diaphragm Valve in a new wide choice of body, disc insert, and diaphragm materials—in unlined or lined patterns. Whichever is specified, Crane design gives you important advantages including—long diaphragm life . . . positive shut-off in case of diaphragm failure . . . less resistance to flow with minimum pressure drop . . . easy operation with reduced torque and fewer turns . . . simplified maintenance at lowest upkeep cost.

Full specification data is in your new Crane 53 Catalog—or ask your Crane Representative.

SCREWED ENDS, UNLINED Sizes ½ to 2 in. Brass, Cast Iron, Aluminum, or 18-8 Mo body and disc. Furnished with neoprene, Buna N, and natural rubber diaphragm and disc insert.

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The meter used by thousands of municipalities in the U. S.

"Watch Dog" models . . . made in standard capacities from 20 g.p.m. up: frost-proof and split case in household sizes. Disc, turbine, or compound type.

SURE TO MEET YOUR SPECIFICATIONS FOR ACCURACY, LOW MAINTENANCE, LONG LIFE.

Before you invest in water meters, get acquainted with the design and performance advantages which make Worthington-Gamon Watch Dog Water Meters first choice of so many municipalities and private water companies in the United States.

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EFFICIENT FLOCCULATION IS A "BAFFLING" PROBLEM

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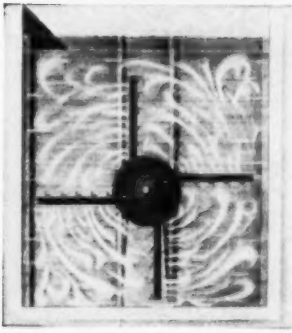
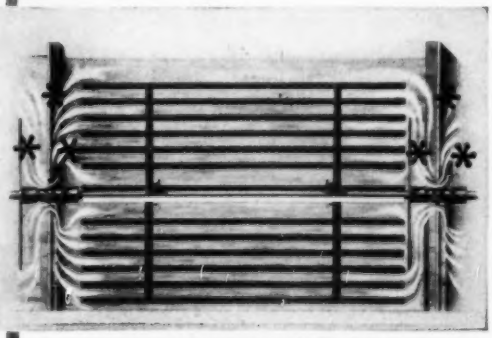
1. All flow directed to active mixing area . . . complete utilization of tank volume . . . practically no short circuiting.
2. Minimum amount of chemical required . . . thorough mixing assures positive reaction of all chemicals.
3. Tapered mixing by zones . . . the proved Langelier Process . . . assures large, readily settleable floc.
4. Extreme flexibility—a variety of paddle speeds, paddle areas, zone lengths and drive arrangements available to suit any conditions.
5. Paddle axis parallel to line of flow . . . all flow receives uniform treatment in each zone.

For all the facts, call your nearest Rex Field Sales Engineer or write for Bulletin 48-39. Chain Belt Company, 4609 W. Greenfield Ave., Milwaukee 1, Wis.



Cross-sectional view from head of tank showing mixing action.



Cross-sectional side view of Floctrol showing flow.

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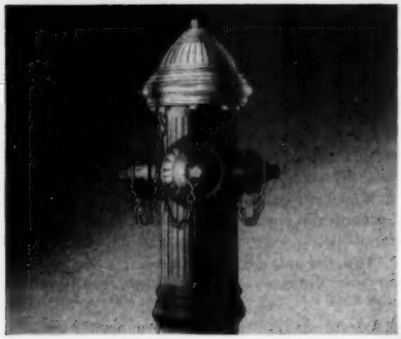

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A.W.W.A. Specification and High Pressure; Compression Type; Frost-Proof Tapered Barrel; Positive Action Drain; Low Friction Loss Maximum Delivery.

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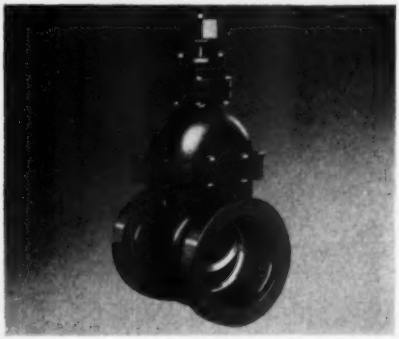
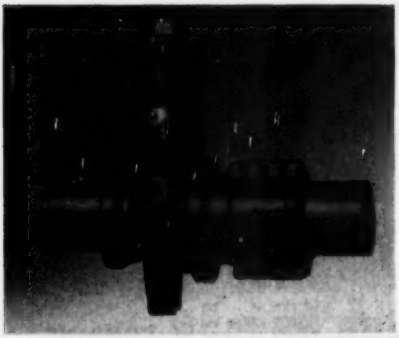
Sizes 2" thru 66" Double Disc, Parallel Seat type for Low, Medium or High Pressure service. Manual, Hydraulic Cylinder or Motor Operated.





INSERTING VALVES

Without interrupting service the Valves are inserted under pressure in Cast Iron and Steel Mains sizes 4" thru 48".

Write for information on other Smith products.

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THE A.P. SMITH MFG. CO.

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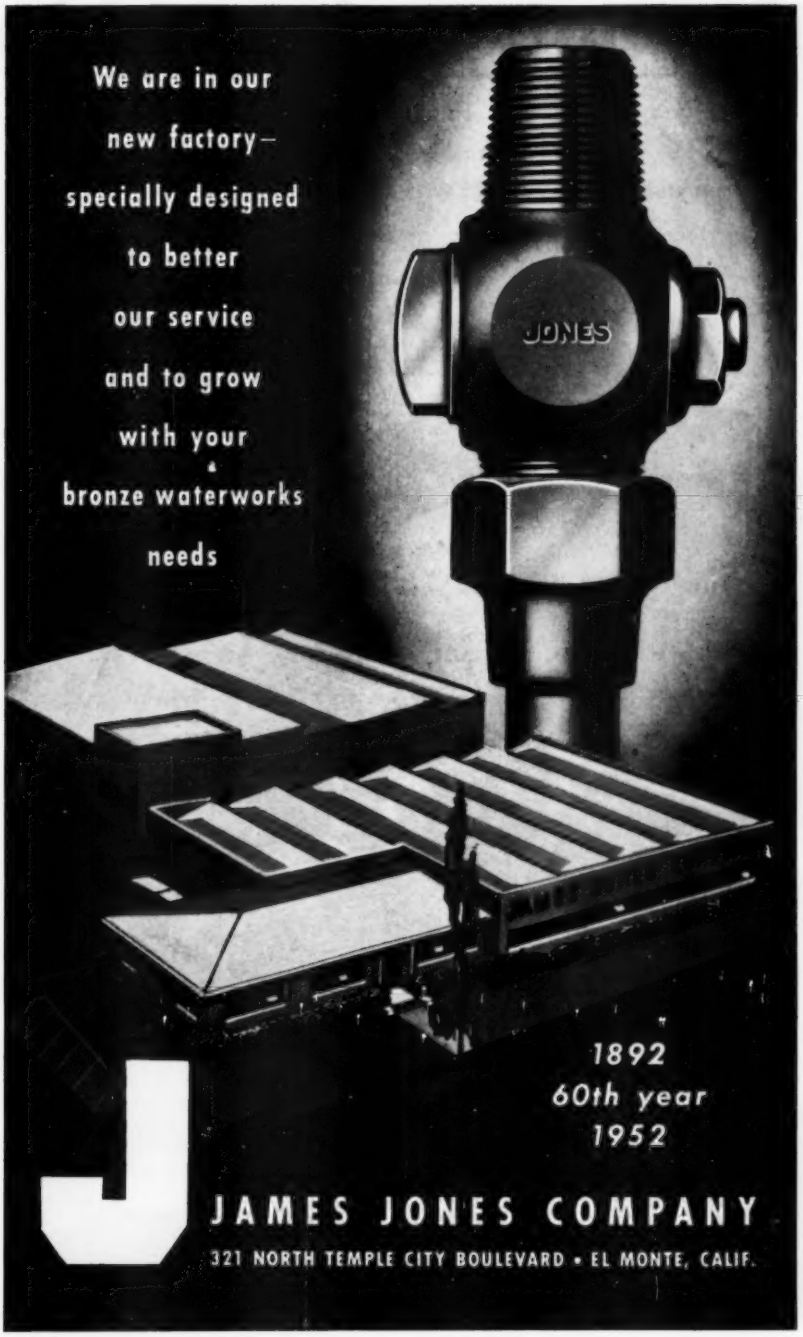
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new factory—
specially designed
to better
our service
and to grow
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JAMES JONES COMPANY
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An ounce of proof is

worth a pound of claims!

For a permanent installation, such as a new water supply system, or extensions to an existing system, experienced engineers rarely take chances on a substitute for cast iron pipe. They know that 96% of all cast iron pipe, 6-inch and larger, laid in 25 representative cities over the past 130 years, is still in service. On the other hand, it is a fact that more than a few communities have had to replace water distribution systems, constructed with substitue pipe, long before the bonds issued against them were paid for.

The long life and low maintenance cost of cast iron water mains—and the consequent tax savings to the public—are matters of record. An ounce of *proof* is worth a pound of *claims!*

One of a number of cast iron water mains which have been in service in New York City for more than a century. Over 35 other cities have century-old cast iron mains in service.

CAST IRON

CAST IRON PIPE

America's No. 1 Tax Saver

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DON'T
SHOW.....
IN W & T CHLORINATORS, EITHER
The unseen roots of a beautiful tree give it life and strength. So, too, do the unseen features back of a W&T Chlorinator—basic research, service, and a complete line of equipment—ensure dependability and trouble-free operation throughout the years.
Basic research, for example, while not necessarily essential to each particular installation, is, nevertheless, the life blood of sound equipment. W&T research developed the Visible Vacuum Principle, residual recording, the Break-Point Process and countless other advances in the art of chlorination. This same research is constantly at work to insure that the W&T equipment you buy is up-to-date in every respect and will not be outmoded before its time.
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Coatings for Steel Water Pipe

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STEEL pipe of various forms, protected with different types of coatings, has been used in the United States since 1860 for the conveyance of water for domestic, industrial, irrigation, and other types of service. Many millions of feet of steel water mains have been installed during these past nine decades. This kind of pipe possesses many advantages, including the five essential requisites of any good water conduit—reliability, strength, high carrying capacity, economy, and durability. When properly designed, protected, and installed, steel pipe will give long and useful service as a water conduit. It does, however, possess one particular disadvantage: when installed bare or improperly protected against oxygen, particularly in the presence of moisture, it will tend to return to its original state of iron oxide. To overcome this affinity of corrosive agents for iron, it is desirable that a permanent coating be applied to the interior and the exterior of the water pipe to act as a barrier against all corrosion attacks. A protective coating of proper type for existing conditions will prevent deterioration of the metal. Pipe laid underground is subject to soil stress, erosion, electrolysis, and chemical, physical, galvanic, and bacteriological action. It is essential, therefore, to determine the magnitude of these various factors so that a completely protective coating can be selected economically and scientifically to offset their detrimental effects.

The purpose of this paper is to assemble and summarize present knowledge on the subject of available coating materials, their effectiveness, and their approximate cost of application. This discussion will be confined to steel water pipe 4 in. or more in diameter, as manufactured under specifications AWWA C201 (*1*) and C202 (*2*). The references listed at the end of this

paper include pertinent literature on coatings (*3–13*), which should be consulted for a more comprehensive review of this subject.

Characteristics of Effective Coatings

The effectiveness of a coating, or a combination of coatings, depends on the completeness and permanence with which it isolates the pipe from corroding elements. In general, the essential qualities of any protective coating are:

1. *Chemical resistance.* The coating should be chemically inert to the soil, air, water, bacteria, and vegetation conditions encountered. It should be chemically neutral to the pipe steel, possess solubility resistance against petroleum products, and remain stable indefinitely.

2. *Physical resistance.* The coating should fully resist physical abuse during transportation, storage, and installation of the pipe and should have sufficient hardness to resist deformation from pressure, soil stress, and extreme temperature changes. It should remain at all times in unbroken contact with the steel surface. It should have a tight bond to resist the tendency of certain soils to contract and pull the coating from the pipe, and to resist the shearing action of the soil if the pipe should move longitudinally. It should possess the important quality of ductility so as to resist cracking from deflection.

3. *Water penetration resistance.* An ideal coating should be completely resistant to the penetration of water, because moisture and oxygen together will cause corrosion of the steel. The coating should have no porosity and, as applied, should permanently waterproof the pipe to the extent that not more than 0.25 per cent by weight of moisture is absorbed into the coating over a period of 250 days.

4. *Dielectric strength.* The sustained electrical resistance of the coating should be at least 100,000 ohms per square foot of surface. The applied coating should have low electrical conductance in order to act as an insulator between the pipe and the soil or water, thereby preventing any electrochemical action betwen the various materials. An approved electrical detector of low amperage and of 100 v per mil thickness, for coal-tar enamel—55 v per mil for asphalt—should be used over the coating surface to detect any holes or thin spots that may exist. The spark length during testing should be set at about twice the thickness of the coating. Good insulation with proper dielectric strength, combined with adequate cathodic protection, will result in complete and enduring protection.

5. *General characteristics.* Other desirable qualities of an effective coating are:

a. High mechanical strength

b. Durability—the coating should be permanent

c. Smoothness—linings should be uniform and smooth to maintain high carrying capacity

d. Ease of application—progress has been made in methods of application of many coatings, and proper application of the coating is just as important as the high quality of the coating itself

e. High bond strength—cleanliness and dryness of the steel surface at the time of coating application is highly important to insure good and continued adhesion of the coating

f. Reasonable cost

g. Resistance to bacteria

h. Resistance to vegetation

i. Resistance to effects of cathodic protection.

Although all of these requirements are desirable, the two most important characteristics for any effective coating are resistance to water penetration and to deformation. If these two requirements are not met by the coating selected, there can be no lasting protection of the pipe. The proper coating for any particular installation is the material or combination of materials that meets economically the greatest number of the requirements called for under the circumstances and has the two all-important characteristics mentioned above.

Pipe wrappings and shields are also considered in this paper. The essential characteristics for these materials are: [1] resistance to water penetration; [2] high dielectric strength; [3] chemical inertness; [4] elasticity; and [5] high mechanical strength.

Types of Coatings

Some of the most common types of coating materials now available for the protection of steel water pipe are:

1. *Asphalt coatings.* There are many types of asphalt coatings, most of which are derived from petroleum. They include hot dips, paints, emulsions, mastics, and enamels.

Asphalt hot dips are used extensively on the smaller sizes of steel pipe because of their ease of application and low cost. They may be practical and economical where soil conditions are favorable and dry. They absorb moisture readily, however, and are not considered a permanent coating.

Asphalt enamel is a much superior coating material to asphalt dip, but it is more costly. Its physical resistance is not very effective and, therefore, it will serve its purpose better if shielded. It possesses some porosity and, consequently, absorbs some moisture because of the loss of oils in the drying action. Its dielectric strength decreases as its moisture penetration increases. It does not resist vegetation very well. It should be applied in a thickness of $\frac{3}{32}$ in.

Asphalt emulsions are applied cold. They are not very effective as a protective coating unless applied with an impervious wrapping. They are porous and have low dielectric strength.

Another product that makes use of asphalt as one of its constituents is asphalt mastic, a hot mixture of sand aggregate and asphalt. It is applied under pressure to the outside of the pipe in a thickness of approximately $\frac{1}{2}$ in. and makes a good coating and shield against soil pressure and impact. It can be furnished on steel pipe $\frac{1}{2}$–30 in. in diameter.

2. *Coal-tar coatings.* Coal-tar enamels are mixtures of coal-tar pitch and fillers. For water lines, plasticized enamel is recommended. The AWWA has developed excellent specifications (*14, 15*) for this material and its application to the interior and the exterior of steel water lines. When spun centrifugally to the inside of the pipe, it becomes extremely smooth and glasslike, thus providing very high carrying capacity. It has good bond when properly applied, and is generally applied in a thickness of $\frac{3}{32}$ in. It will resist the effects of temperature over a wide range and is considered to be a stable, permanent material. It has low water penetration and high dielectric strength. On the exterior of the pipe, however, it will not completely resist soil stress or plant life. It serves well when applied under a shield.

Coal-tar paints also have been used on water lines but are not nearly so effective as the enamel.

3. *Cement-mortar coatings.* These types of coatings have been used for

many years on water lines with varying degrees of success but generally good results. They provide satisfactory corrosion resistance under dry conditions but deteriorate under salt water or sulfate conditions. Electrolysis will disintegrate mortar coatings under certain conditions. Because of its hardness, this material resists vegetation, except in cracks. It does not have sufficient dielectric strength to be effective against electrical currents. When applied on the exterior over a waterproofing material, it becomes an effective coating and an excellent shield. It is not very flexible and cracks readily on account of its low tensile strength. It possesses high resistance to soil stress.

The inside lining is usually applied centrifugally in thicknesses of $\frac{1}{4}$–$\frac{1}{2}$ in., while the outside coating generally is shot onto the pipe in a thickness of $\frac{3}{4}$ in. and reinforced with wire mesh. Linings and coatings can be applied in shop or field and have been used satisfactorily in the rehabilitation of old pipelines in place.

The thickness and mix proportions control the effectiveness of mortar coatings, and a modified standard cement seems to give the most effective results.

4. *Petrolatum coatings.* This type of coating is made from refined petroleum and contains no asphalt or coal tar. It is generally described as a "grease" coating containing an inhibitor. It can be furnished in various degrees of fluidity and can be applied by brushing, spraying, or rubbing. It does not harden or dry and remains stable for a long time. It requires careful handling, however, as it is soft and pliable. It will not resist soil stress unless covered with a shield. It resists cold, but not heat, and repels moisture. It is easy to apply and should be at least 100 mils thick to obtain good results. It possesses low dielectric strength and is used on the exterior of pipe only.

5. *Vitreous-enamel coatings.* This coating is a glass material fused to the pipe surface at high temperature. It has good bond but is somewhat porous. It has excellent dielectric strength, high soil stress resistance, chemical resistance, and good resistance to temperature changes. It has only fair ductility and is difficult to apply. It is applied generally in a thickness of $\frac{1}{32}$ in. and is relatively high in cost for use as a coating on ordinary steel water pipelines.

6. *Synthetic-resin coatings ("plastics").* These coatings are divided into two general types—thermosetting (phenolformaldehyde) and thermoplastic (cellulose). A good bond is obtained from the baking process. Some of the advantages of these coatings are: [1] chemical inertness; [2] high dielectric strength; [3] low moisture penetration; and [4] permanence. At present, however, these resin coatings are too costly for the average water pipe installation.

7. *Rubber coatings.* Rubber can be applied in sheet form, solution, or powder, although sheet rubber will give the best results. Rubber linings in steel pipe will resist many acids and chemicals, but they are slow to apply and are very expensive. Consequently, they are used only for special conditions, even though they give excellent results.

Thiokol plastic coating also gives good results, but it is likewise too costly for water lines.

8. *Metallic coatings.* These coatings usually consist of zinc, copper, cadmium, tin, chromium, or lead. They are not entirely effective against soil corrosion because of their porosity. They are easy to apply, however. The most common type of metallic coating used on steel pipe is zinc, because of its

relatively low cost and ease of application. It gives a durable coating and is extensively used on small-diameter steel water service lines.

9. *Paints.* There are many forms of paint on the market. Each type consists primarily of pigment and vehicle. Pigments are frequently derived from lead or zinc compounds, while vehicles (the liquid portion of the paint) generally consist of drying oils or resins. For many years red lead has been used as a primer for steel surfaces. Recently, however, other primers have been developed which are superior to red lead. One of these is red chromate primer, which contains 53.7 per cent potassium chromate and zinc chromate combined.

Paints are used generally for surfaces exposed to the atmosphere. For pipelines laid aboveground, it is good practice to apply to the exterior a primer followed by aluminum paint. A properly painted pipe of this kind will be protected adequately for many years. In underground installations, however, paints have little value against corrosion, as they are affected adversely by soil and water conditions. The U.S. Bureau of Reclamation has published a very comprehensive and up-to-date manual on the subject of paints and related products (*3*).

10. *Primers.* Primers act as a bonding agent between a coating and steel surface. They must be applied on clean, dry surfaces at proper time and temperature for best results. They should flow readily so as to penetrate the surface thoroughly and should not be too thick. The steel surface can be prepared clean for a primer by mechanical means, sand- or shotblasting, flame, pickling, or solvents.

Primers are needed with asphalt enamels, coal-tar enamels, and paints, but are not required for mortar coatings, petrolatums, or cold-applied coatings.

Wrappings or Shields

Wrappings or shields envelop the pipe and external coating to protect it against physical forces, such as soil stress and handling, and act as a sealer for the undercoating. They should be nonabsorptive, strong, flexible, hard, resistant to bacteria and vegetation, and capable of maintaining high dielectric strength. They should resist extreme cold or heat and should not be susceptible to cold flow. Wrappers should be well bonded to the coating, nonporous, and impregnated with a waterproofing material.

Wrappings or shields should be used whenever soil or water conditions would cause damage to an exterior coating applied alone, or if the coating might be injured during transportation or laying operations in the field.

Various types of wrappings now available include:

1. *Organic wrappings.* These wrappers consist of rag felts, cotton fabrics, burlap, and the like. They are flexible and easy to apply but are not considered permanent because they absorb moisture and do not resist soil stress or bacterial action very well. Felt wrappings should have a strength of at least 30 lb per inch of width. Felt with a strength of 60 lb per inch is most effective.

2. *Inorganic wrappings.* These wrappers consist of thin sheets of copper, aluminum, and the like, as well as cement mortar, asbestos felt, fiber glass, plastic tapes, and cellophane. The copper and aluminum sheets are not used on water lines because of their high cost, but mortar coatings and asbestos felts are widely used, with excellent results. Asbestos felts generally have a nominal weight of 15 lb or 23 lb per

100 sq ft. A saturant is added to act as a filler and to give pliability to the finished product. Asbestos felts are easy to apply, resist water penetration, and are chemically inert to soil and water.

Fiber glass is used generally as a reinforcement for asphalt or coal-tar enamel coatings. It is wrapped in conjunction with the hot coating so as to become anchored therein. It is very light in weight and is chemically inert to all soil conditions.

A relatively new type of wrapping is the cold-applied plastic tape, and tests conducted on it have been very favorable (*7*). These tapes are tough, pliable, and high in dielectric strength, insulation resistance, and chemical resistance. They have low moisture absorption and resist such corrosive elements as bacteria, oils, water, alkalies, acids, vegetation, stray ground currents, and the like. They are obtainable in various thicknesses and widths, are easy to apply, and maintain good bond. Tapes are somewhat expensive as yet, but offer excellent possibilities as wrappers for steel water pipe and fittings.

Cellophane in one or two layers has occasionally been used as a pipe wrapper.

Kraft paper is frequently used on steel pipe as a wrapper over the main wrapper in order to add some measure of protection during handling, transportation, and installation of the pipe. The wrapper helps to reduce the temperature of the pipe when it is exposed to the sun, and it indicates any damage to the coating that may have occurred during the handling operations. Kraft paper will shrink and tear if it absorbs moisture. It is not intended to act as a permanent wrapper. In lieu of kraft paper, whitewash is often used on the main wrapper or coating.

Design Features

In determining the proper amount and type of protective coating and wrapping to be used on any particular water pipe installation, it is essential that a survey of soil and water conditions along the pipeline route be conducted in advance of the coating design. A wide knowledge of all factors involved in corrosion should be obtained for every installation. Field observations and measurements of topographic features, climate, and accessibility should be made and laboratory tests conducted to ascertain the chemical and electrical characteristics of the soil and water, including soil resistivity, stray currents, and galvanic action. These results should then be considered with

TABLE 1

Economical Limits for Protective Coatings

Soil			Estd. Life of Bare Pipe yr	Recommended Protective Coating
Class	Description	Resistance ohm/cc		
1	excellent*	over 6,000	over 25	none
2	good	6,000–4,500	25–17	not to exceed 10% of first cost of pipe
3	fair	4,500–2,000	17–10	not to exceed 20% of first cost of pipe
4	bad	2,000–0	10–1	not to exceed 40% of first cost of pipe

* Such soil is excellent, except where soil resistivity in adjacent areas has wide variations.

TABLE 2

*Maximum Economical Cost of Protected Steel Pipe**

Estd. Useful Life of Protected Steel Pipe, yr	Estd. Useful Life of Bare Steel Pipe—yr										
	10	15	20	25	30	35	40	45	50	60	70
	Max. Economical Cost of Protected Pipe per Dollar Cost of Bare Pipe—$										
Cost Capitalized at 4% Compounded Annually											
10	1.00										
15	1.37	1.00									
20	1.68	1.22	1.00								
25	1.93	1.41	1.15	1.00							
30	2.13	1.56	1.27	1.11	1.00						
35	2.30	1.68	1.37	1.19	1.08	1.00					
40	2.44	1.78	1.46	1.27	1.14	1.06	1.00				
45	2.55	1.86	1.52	1.33	1.20	1.11	1.05	1.00			
50	2.65	1.93	1.58	1.38	1.24	1.15	1.09	1.04	1.00		
60	2.79	2.03	1.66	1.45	1.31	1.21	1.14	1.09	1.05	1.00	
70	2.88	2.10	1.72	1.50	1.35	1.25	1.18	1.13	1.09	1.03	1.00
Cost Capitalized at 5% Compounded Annually											
10	1.00										
15	1.34	1.00									
20	1.61	1.20	1.00								
25	1.83	1.36	1.13	1.00							
30	1.99	1.48	1.23	1.09	1.00						
35	2.12	1.58	1.31	1.16	1.07	1.00					
40	2.22	1.65	1.38	1.22	1.12	1.05	1.00				
45	2.30	1.71	1.43	1.26	1.16	1.09	1.04	1.00			
50	2.36	1.76	1.46	1.30	1.19	1.11	1.06	1.03	1.00		
60	2.45	1.82	1.52	1.34	1.23	1.16	1.10	1.06	1.04	1.00	
70	2.50	1.86	1.55	1.37	1.26	1.18	1.13	1.09	1.06	1.02	1.00

* Read down the column headed by the estimated number of years of useful life of bare steel pipe; read across the appropriate row for the estimated useful life of the same pipe when protected; the figure at the intersection shows the maximum economical amount (in dollars) which can be spent for protected steel pipe *per dollar cost of bare steel pipe*. Subtracting $1.00 from this figure, the difference will be the maximum economical premium (per dollar cost of bare steel pipe) which can be paid for the protective coating.

The ratios shown in this table assume that capitalized and maintenance costs are equal for bare and protected pipe. The capitalized cost is the first cost plus the present value of a perpetuity required to renew the project indefinitely.

regard to the desired service life of the water line. Using the data from such a comprehensive survey, the design engineer can recommend and select the right protection for each section of the line. He will determine, also, the advisability of employing cathodic protection at any specific location.

Table 1 indicates the economical cost limit for protective coatings, taking into consideration soil class, soil resistivity, and first cost of the bare steel pipe.

Table 2 may assist the designing engineer in determining the value of protective coatings from the standpoint of amortization. From this table can be determined the maximum percentage of premium economically justified for a desired extension of the life of steel pipe.

The selection of an interior coating for steel water lines should be made on the basis of permanently maintaining high flow capacity by preventing tuberculation throughout the life of the pipe. The two types of lining most commonly used for this purpose, at present, are cement mortar and coal-tar enamel.

The selection of an exterior protection requires mature judgment on the part of the engineer after all of the various factors have been reviewed. By following modern scientific methods of determining the degree of corrosiveness to be resisted, it becomes possible to select coatings which provide adequate protection without excessive cost.

The ideal protection would combine the protective properties of a coating and a shield in one material. A careful study of all of the individual coatings and shields included in this paper, however, will show that no single coating material universally fulfills all requirements. Therefore, in selecting the proper protection for an installation, it becomes expedient to consider a composite protection that will be as effective as possible at a reasonable cost.

Tables 3–5, showing the relative rating of various characteristics of coatings and wrappings, are intended to condense the contents of this paper for the benefit of the engineer, operator, and management.

Cost of Applied Coatings and Wrappings

Table 3 indicates the approximate current applied cost per square foot for each individual type of coating material. These figures represent the cost of cleaning the pipe surface and furnishing and applying the material to one surface. The approximate unit cost of cleaning included in the coating cost is 2 cents per square foot for wire brushing and 7 cents per square foot for shotblasting. For large quantities of pipe coated on a production line, however, the coating costs shown in the table can be reduced considerably. To obtain exact costs for any major installation, inquiry should be made of an established coating applicator.

For estimating purposes only, the cost per square foot for various types of single wrappings applied to the pipe

TABLE 3

Relative Major Characteristics of Available Coating Materials for Steel Pipe

Coating Material	Chemical Resistance	Physical Resistance	Water Penetration Resistance	Dielectric Strength	Soil Stress Resistance	Durability	Smoothness	Approximate Cost Applied (1 Surface) $/sq ft
Asphalt dip	fair	fair	low	low	fair	fair	fair	0.02
Asphalt emulsions	low	low	low	low	low	low	low	0.03
Asphalt enamel	fair	fair	low	fair	fair	fair	high	0.20
Asphalt mastic (outside)	fair	high	fair	fair	high	high		0.20*
Coal-tar enamel (outside)	high	fair	high	high	fair	high		0.25
Spun coal-tar enamel (inside)	high	high	high	high		high	high	0.25
Spun mortar lining	fair	high	low	fair		high	high	0.30
Mortar coating (outside)	fair	high	low	fair	high	high		0.35
Petrolatum coatings (greases)	fair	low	high	low	low	low	low	0.10
Vitreous enamel	high	fair	high	high	high	high	high	costly
Synthetic resins (plastics)	high	high	high	high	high	high	high	0.50–1.00
Rubber	high	fair	high	high	fair	high	fair	3.50
Metallic coatings	fair	fair	high	low	high	high	fair	0.60–0.75
Paints	fair	fair	low	low	fair	fair	fair	0.10

* This cost applies in West; cost in East may be higher.

can be taken as follows: 15-lb asbestos or 40-lb rag felt—5.5 cents; 23-lb asbestos felt—7.5 cents; 15-mil fiber glass—5.5 cents; 80-lb kraft paper (or whitewash)—3 cents.

For any combination of coatings and wrappings, the approximate cost can be determined by adding the corresponding cost of each single type. For example, assuming a 16-in. diameter pipe coated with coal-tar primer, coal-tar enamel, fiber glass matting, 15-lb asbestos felt wrapping, and kraft paper, the estimated cost of the complete protection would be $25 + 5.5 + 5.5 + 3 = 39$ cents, per square foot, or $1.65 per foot of pipe.

TABLE 4

Relative Minor Characteristics of Available Coating Materials for Steel Pipe

Coating Material	Bond Strength *psi*	Ductility	Max. Temp. °F	Flow Temp. °F	Freezing Resistance	Ease of Application	Approximate Thickness *in.*	Resistance to Abrasion	Deflection Resistance	Porosity
Asphalt dip	100	fair	350	150	fair	high	$\frac{1}{8}$	fair	high	fair
Asphalt emulsions	low	fair	150	100	fair	high	0.065	low	high	high
Asphalt enamel	150	fair	400	160	fair	fair	$\frac{1}{32}$	fair	high	low
Asphalt mastic (outside)	fair	fair	350	220	high	high	$\frac{1}{8}$	high	fair	fair
Coal-tar enamel	150	high	485	160	high	fair	$\frac{1}{32}$	high	high	low
Spun mortar lining	low	low	120		low	fair	$\frac{1}{4}$-$\frac{1}{2}$	high	low	high
Mortar coating (outside)	low	low	120		low	fair	$\frac{1}{2}$	high	low	high
Petrolatum coatings (greases)	low	fair	140	80	high	high	0.100	low	high	fair
Vitreous enamel	3,000	fair	1,600	1,000	fair	low	$\frac{1}{32}$	high	low	fair
Synthetic resins (plastics)	high	high	300	150	high	fair	0.006	high	high	low
Rubber	500	high	180		fair	fair	$\frac{1}{8}$	high	high	low
Metallic coatings	high	high	850		high	high	0.006	high	high	fair
Paints	fair	fair	150	100	fair	high	0.006	fair	high	high

Conclusions

Experience and tests on many types of coatings and wrappings for the protection of steel water lines have established the following facts (*4, 6–8*):

1. Protective coatings, to be permanent and economically justifiable, should have substantial thickness.

2. No protective coating, regardless of its intrinsic effectiveness, can give satisfactory or durable protection unless it is properly applied to steel surfaces that are in proper condition to receive it.

3. Asbestos felt wrappers, mortar coating shields, or their equivalents, so greatly increase the service life of coatings that their use gives a return on the investment far in excess of their cost.

4. The most common linings now in use for water lines are cement mortar and coal-tar enamel. Other types of materials, such as phenolic, vinyl, thiokol, vinyl-thiokol, and neoprene materials, also offer good possibilities (*7*).

5. To resist low temperatures, coal-tar enamel linings should have a penetration, as applied, of at least 7. Furthermore, coal-tar enamel coatings should be shielded with a substantial wrapper so as to be fully effective against soil and water conditions.

6. Cold-applied vinyl and polyethylene tapes seem to be satisfactory for protecting buried steel pipe and appear especially appropriate for use on welded field joints.

It is a known fact that buried steel pipe, if installed bare or improperly protected, will eventually corrode. The buried pipeline represents a large in-

TABLE 5

Relative Characteristics of Available Pipe Wrapping Materials

Material	Chemical Resistance	Physical Resistance	Water Penetration Resistance	Dielectric Strength	Soil Stress Resistance	Durability
Rag felt	fair	fair	low	fair	fair	fair
Asbestos felt	high	fair	high	high	fair	high
Fiber glass	high	high	high	high	high	high
Osnaburg	low	fair	low	low	low	low
Sheet metal	high	high	high	low	high	high
Cellophane	high	high	high	high	fair	high
Plastic tape	high	high	high	high	high	high
Kraft paper	low	low	low	low	low	low

vestment. It is not readily accessible to inspection; and if corrosion occurs and makes reconditioning or replacement necessary, an additional heavy expense results to the owner. Furthermore, the corrective measures will cause interruption in service, loss of operating revenue, property damage hazards, and so forth. Therefore, it behooves the engineer, operator, and management alike to design, construct, and operate any pipeline on a sound and economical basis, corresponding to the actual conditions to be encountered in the field. If this procedure is followed faithfully with regard to the proper coatings to be selected for each installation, the owner can be assured that his pipeline will render many years of useful and economical service.

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Cement-Mortar Linings and Coatings for Steel Pipe

By R. C. Kennedy

A paper presented on Oct. 30, 1952, at the California Section Meeting, Pasadena, Calif., by R. C. Kennedy, Chief Engr., East Bay Municipal Utility Dist., Oakland, Calif.

THE ideal steel pipe coating must have the following principal characteristics:

1. It must be physically strong and tough enough to absorb without injury the rough handling it may receive in hauling and installation.
2. The bond to the pipe surface must withstand the stresses from the soil in which it is embedded and the shearing force caused by slight longitudinal movements of the pipe.
3. The chemical interaction with the steel surface must not be such as to cause corrosion.
4. The water absorption of the material should be low.
5. The electrical resistance must be uniformly high over the entire surface of the pipe.
6. The material must not deteriorate with age.
7. The material must be such that uniform quality can be maintained in spite of normally changing climatic and other conditions during application.
8. The overall cost must be reasonable in comparison with other materials, with due regard for cost of maintenance and length of life.

If the material is to be used also for lining the pipe, the surface must remain uniform and smooth permanently.

Many years of experience with the lining, coating, and installation of approximately 150 miles of steel pipe in all sizes up to 67 in. has convinced the author that cement mortar fulfills most of the requirements mentioned.

The value of cement mortar for lining cast-iron pipe has long been recognized, both in the United States and abroad. In 1836 the French Academy of Science reported: "Hydraulic cement is, of all compositions combining facility of application and cheapness, that which adheres best to casting, is most indestructible and prevents most effectually all [corrosion]" (*1*).

The earliest record of a cement-mortar lining being used in the United States appears to be at Jersey City, N.J., where in 1845 a sheet-iron pipe was lined with natural cement mortar before laying and was still in excellent condition when removed from service a few years ago (*1*).

Ingenious modern methods make possible the lining of steel pipe either as a part of the manufacturing process or after installation. The most common type of shop application is by the centrifugal method, using a mix of 1:3 or richer, and a thickness of $\frac{3}{8}$–$\frac{1}{2}$ in. By careful control of the speed of rotation, the excess water is squeezed out and the lining is rendered uniform in thickness and very smooth, with a thin layer of rich mortar at the surface. The lining is then cured in high-humidity air.

Tests by the East Bay Municipal Utility Dist. conducted in 1936 on sections of a 24-in. pipeline showed Hazen-Williams *C* values varying from 145 to 152. Ten years later, the line was again tested, with practically identical results.

The 67-in. Second Mokelumne Aqueduct, also cement-mortar lined, was tested shortly after installation in 1949 and showed a *C* value of 147.3 in a 50-mile section of fairly straight pipe with few constrictions or obstructions.

A few hundred feet of the district's 54-in. Wildcat Aqueduct was removed in 1951 because of street changes. The pipe is of the vertically cast steel cylinder type. Close examination revealed that, after 23 years of use, the interior surface is practically like new except for a slight sandpaper effect, due apparently to the solution of some cement by the soft water carried. Where the lining or coating was chipped off in the examination, the steel showed no deterioration.

It would appear to be a safe assumption that the permanent coefficient for a steel pipe lined with cement mortar by the most modern techniques and carrying water of normal pH will be approximately 145, based on the net diameter—that is, inside the lining. By "permanent" the author means at least 100 years, which is as long a period as is important in choosing between alternate designs in most engineering structures.

Early methods used by the East Bay Municipal Utility Dist. in coating steel pipe with cement mortar involved wrapping the pipe with 2 × 4-in. 13-gage welded wire mesh reinforcement and applying the mortar over this with a cement gun. Although this method was successful, difficulty was sometimes experienced because of sagging of sections of the coating, which then had to be cut out and replaced. It is highly probable that some defective areas of this nature were not discovered. The method now followed is to wrap the bare pipe with ¼-in. or larger rods spaced about 2 in. apart and applied under considerable tension. The cement mortar is applied over this rod with a cement gun or by mechanical means. The bond thus secured is very high and results in remarkable stiffness of the pipe shell against collapse. If sections of the coating are broken with a hammer, the cleavage will generally occur along the centerlines of the rods rather than at the pipe surface.

Paul and Eide (*2*) have described tests made by the district on a 48-in. pipe consisting of ¼-in. steel plate with ½-in. cement-mortar lining and ⅜-in. coating. The wire reinforcement was ¼ in. at 2 in. centers, applied with an initial stress of 5,000 psi. The pipe was buried in a trench to simulate normal installation, and the air was removed by a vacuum pump. No collapse occurred although almost a complete vacuum was attained. A 36-in. pipe, $\frac{3}{16}$-in. thick and similarly lined and coated, sustained an external liquid pressure of 76 psi before collapse—approximately 600 per cent higher than the computed strength of a bare cylinder of the same size and thickness. Such shell stiffness is of great value in saving the expense of vacuum valves, in supporting deep backfills, and in protecting the lining and coating during the handling of the pipe sections.

Cement mortar in intimate contact with a steel surface provides an alkaline environment, a condition which protects the metal from corrosion. According to Speller (*3*), the initial rate of corrosion in alkaline solutions is roughly the same as in neutral solutions, but the rate of corrosion decreases in the alkaline solution because

of the formation of a protective film of ferrous hydroxide rust on the metal surface. This film insulates the metal from electric-current flow and thus largely stops further corrosion.

Although cement-mortar coated pipe has been used by the district for installations in every type of soil, only two corrosion failures have been experienced with such a coating. Both were in a 24-in. line installed in 1936. At points where the pipe crosses small swamps, the coating disintegrated and the steel corroded through in a period of 14 years. It was found that the line was carrying an electric current which discharged from the pipe into the wet soil at the points of failure. The pipe was repaired and cathodic protection was installed to reverse the current flow. This measure seems to have solved the problem completely.

These failures bring out the only apparent weakness of cement-mortar coatings. As the material has some degree of porosity, if the ground is wet and, particularly, if the ground water contains salts in solution, electric current can pass through and disintegrate the coating. An undercoating of bituminous material has been used by some engineers, but this interferes with the bond of the cement mortar, particularly if the rod-wrap method is employed. Also, some crevices in the undercoating under such conditions could invite a concentrated electric discharge at these points, resulting in rapid perforation of the steel. The author believes that the mortar should be applied to the bare metal and that insulating joints or cathodic protection should be provided to stop the flow of long-line currents. A possible additional or alternative precaution would be to apply a bituminous material over the coating in bad-soil areas, thus reducing the porosity and increasing the electrical resistance.

Pipe of the so-called "modified prestressed concrete cylinder" design employs a relatively thin steel cylinder which, after lining, is wrapper with rod under predetermined tension. This procedure places the cylinder and lining under initial compression. By proper selection of the type of steel used in the cylinder and rod, both will be brought to the desired working stress when the pipe is under the designed pressure.

One of the most valuable characteristics of cement mortar as a lining or coating is that the success of the material is not affected by minor variations in the mix, the surface of the steel, or weather conditions during application. The surface needs only to be clean. Moisture, of course, is unimportant, and mill scale or spots of rust do not have to be removed. Because the equipment required for application is not of great complexity, it can be moved to the site of the work for a job of considerable size, thus obviating transportation of the heavy lined pipe sections.

With proper application and in normal soil conditions, cement-mortar coatings are permanent, in the usual sense of the term. Also, cement linings in pipes carrying water of sufficient hardness not to dissolve the lime of the cement do not appear to be materially affected by age. Consequently, it may be assumed that the first cost is the only cost in such installations.

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Cost Control—Building Net Revenue

By W. Victor Weir

A paper presented on Nov. 19, 1952, at the Water Works Management Short Course (conducted Nov. 19–21, 1952, by the Business Management Service, College of Commerce and Business, University of Illinois, at Monticello, Ill., and sponsored by the In-Service Training Committee, Illinois Section, AWWA), by W. Victor Weir, Pres. & Gen. Mgr., St. Louis County Water Co., University City, Mo.

THE management tool, cost control, has been developed and utilized extensively by competitive industry to accomplish two things: first, to enable the establishment of proper prices to cover the articles produced and sold; and second, to enable management to watch the costs of production so that the finished costs will be less than the prices at which the goods are to be sold.

The water works industry has been slow in adopting cost control as an ordinary management tool, principally because the element of competition is lacking. Other public utility services have adopted cost control to a greater extent than has the water works industry, because they do experience competition even though they also operate as monopolies. The products and services of the electric, gas, and transportation utilities are definitely in a competitive field.

Cost control may be defined as the obtaining of minimum operating costs and resultant maximum net revenues by preparing, considering, and acting upon cost analyses. "Cost accounting," an essential element of cost control, is defined as "that method of accounting which provides for the assembling and recording of all elements of cost incurred to accomplish a purpose, to carry on an activity or operation, or to complete a unit of work or a specific job" (*1*).

Cost Control Procedure

Cost control has three primary elements, all of which must be carried through to completion if full benefits are to be obtained:

1. Management must set up the tools it needs, principally general-accounting and cost-accounting systems. Although most utilities do have general-accounting systems, the practice of cost control may require modifications so that management can obtain the accounting information it needs. Cost-accounting practices utilize much data assembled in general accounting, but, in addition, require a number of specialized accounting procedures.

2. Management must review, on as current a basis as possible, the accounting and cost information reported to it.

3. Management must act to improve the personnel, organization, operating facilities, and operating practices, as indicated by its analyses of the cost information.

The accounting procedures involved in cost control include:

1. *General accounting—operating information.* Proper general-accounting practices will produce, or should be made to produce, information covering: revenues; operating expenses; maintenance expenses; depreciation; taxes; interest and other income deductions; and net income. Certain other information, depending upon the specific utility involved, will also be produced. The categories mentioned are only the primary ones.

2. *General accounting—property information.* Good general-accounting practices will produce monthly and annual information on the costs of property additions and retirements, by property classification. Inasmuch as installation of property causes certain expenses generally termed "overhead," the general-accounting practices will develop the overhead charges which should be made to the various property accounts.

3. *Customer accounting and collecting.* Although accounting information of this type may not appear to be essential in the practice of cost control, it is valuable to management, which must know where the product is going, the percentage being delivered to various types of customers, whether their payments for the product and service compensate for the costs involved, and whether the amounts owed are being collected. The basic data required are: sales, by customer classification; revenue, by customer classification; and collections and delinquencies.

4. *Expenditure accounting.* Accounting in this category is usually in addition to general accounting. The activities involved cover:

a. *Purchasing.* All utilities follow purchasing practices which range from well organized to chaotic. A satisfactory purchasing procedure calls for the organization of the steps involved, and the institution of control when necessary, to meet the needs of each specific utility operation. Variations are dependent upon the size of the utility and whether or not utility purchases are combined in any manner with other departmental or utility activities.

b. *Stores—materials and supplies.* Water works materials and supplies are used for operations, maintenance, or construction of new facilities. Expenditures for such materials and supplies must be properly accounted for, to enable charges to be made to the specific operations or jobs involved. Internal organization and control are necessary, not only to show the use of, but also to prevent the loss of any stores.

c. *Contractual services.* Water utilities incur expenses for services or equipment provided by outsiders. These items include construction by contract, rent, insurance, transportation services, telephone, and postage. As these expenditures are often a large part of the total, the accounting procedures should record such expenses in reasonable detail, by categories.

d. *Equipment.* Cost data must be kept covering the principal individual pieces of equipment—such as transportation units, heavy construction machinery, and costly office equipment like billing machines—in order to enable management to determine when such items should be replaced. Cost records for smaller items, such as meters, may be kept by groups of similar units.

e. *Payroll.* A large part of the utility's total expenditures is the payroll for wages and salaries. Because the work involved covers both operations and construction, expenditures for pay-

roll must be properly allocated. In addition to the dollars involved, summary data concerning the number of employees, hours of work, and the like must be kept if management is to use payroll information to gage the efficiency of operations.

5. *Cost accounting.* The accounting and statistical data must be further developed to produce, first, suitable units for each classification of operation and property which is to be subject to cost control; and, second, figures for the cost of these units of performance or property. A work order system must be followed to allow the identification of costs chargeable to individual jobs or projects.

6. *Reports.* Management, to exercise cost control, must receive periodic reports of the various items involved. These reports are made daily, weekly, monthly, and annually, depending upon the fluctuations in pumpage and sales, the employees' work load, and the need for making changes in operating and construction schedules and practices. The reports will normally be prepared by the persons handling general- and cost-accounting work, although, in small utilities, they may have to be prepared by management personnel. The reports are of three types: financial—operating, maintenance, and property; statistical—tabulations and graphs, presented in the manner which will best show the statistics involved; and performance—covering operations and installation of property additions.

Aims of Cost Control

The proper use of cost control allows management to: [1] measure the work loads of employees and groups of employees; [2] determine the efficiency of employees, equipment, and practices; [3] measure the capability of employees and equipment to meet potential demands for water and service; [4] plan the economical expansion of facilities to handle growth; and [5] budget for future expansion and construction.

The accounting and other information developed in cost control is generally applied to the comparison of present with past unit costs and the comparison of unit costs with similar unit costs in other utilities. The latter is only possible if standard units and standard accounting practices are used by the utilities being compared. Accounting classifications recommended by the National Assn. of Railroad and Utility Commissioners have been adopted by many public service commissions for use by privately owned and operated utilities. Municipally operated utilities which have adopted this classification system may also be able to make comparisons of unit operating and construction costs.

Unit Costs

In the category of operating and maintenance expenses, determination of the following unit costs is desirable:

1. Operating expenses, by classification, per thousand or million gallons pumped and per average customer supplied, for the current month and for the elapsed period in the current year, with comparable figures for the same period of the previous year or years.

2. Maintenance expenses, by property classification: pumping and purification, per thousand or million gallons pumped; mains, per mile in service; services, meters, and fire hydrants, per unit.

Unit costs of property items, subdivided into material, labor, contractual

service, overhead, and so forth, are desirable for the installation of:

1. Water mains—per foot for each size
2. Services—per unit and per foot for each size
3. Meters—per unit for each size
4. Hydrants—per unit for each size.

Statistical reports are necessary, covering, but not limited to, the following:

1. Customers—monthly increase and cumulative number
2. Water pumped—monthly and cumulative for year
3. Water used in company operations, at the plant, in the meter department and for construction purposes—monthly and cumulative for year
4. Water sold—monthly and cumulative for year, with reasonable estimates being made for unmetered sales
5. Ratio of water sold to net water delivered to the distribution system (this ratio should be considered the percentage of water accounted for)
6. Fuel or power used—monthly and cumulative, by operating classifications
7. Cost of fuel or power used by each operating classification and per million gallons pumped in each operating classification
8. Chemicals used—in pounds, by chemical name
9. Cost of chemicals, classified by units of each chemical and per million gallons produced.

Practices Subject to Cost Control

The application of proper cost control procedures by management will allow conclusions to be reached and decisions to be made concerning:

1. Kind of power to be used for pumping
2. Desirable sizes of plant units and facilities
3. Materials for and sizes of water mains
4. Method of installation of facilities—that is, force account or contract
5. Selection of equipment of various kinds
6. Choice of alternate facilities, such as between distribution storage, transmission mains, and booster pumps, or between elevated and surface storage.

Operating practices which lend themselves to cost control are:

1. Establishment of plant operating schedules, which may be affected by personnel costs, purification costs, pumping costs, and changing demands placed upon the system by customer use.
2. Selection of optional power rate schedules which may carry varying demand and energy charges, to obtain the lowest power costs for handling the pumping schedule required to meet customer demands.
3. Meter repair practices, particularly the economics of repairing or replacing meters.
4. Determination of efficiency of personnel, particularly the work load of individuals and groups, and the desirability of shifting employees between work classifications when work load changes occur.
5. Determination of the efficiency of equipment to give information on the need for maintenance or replacement.

Difficulties Encountered

An element in the comparatively small use of cost control in the water industry is that water works management frequently includes persons who do not understand the benefits which can be obtained from proper and more complete accounting information.

Management often is, or thinks it is, too busy to spend time studying accounting data.

Management may be reluctant to spend money on accounting procedures having only indirect value. Too often the tendency is to require less, rather than more, accounting information, with the result that the accounting information produced is of little worth in operating a utility property.

Employees are reluctant to perform the paper work involved in accounting and cost control. They are more interested in work where the accomplishments are evident. Constant pressure must be put upon employees to report promptly and accurately all work done.

The accounting reports may be made too late to be of maximum value. As previously stated, daily and weekly reports are sometimes needed. For practically all operations, monthly summaries should be made. Annual reports are of minor importance in cost control, as they are reporting ancient history by the time they are developed.

Recommendations

It is recommended that those responsible for the management of a water utility should:

1. Compare the accounting practices of their utility—particularly cost and expenditure accounting—with recommended standards. Outside accountants may help with this comparison. The *Manual of Water Works Accounting* (*1*) covers these subjects excellently.

2. Determine what cost information is desired and set up a system to produce it. A modest beginning is best.

3. Check the various records being kept and reports being made to determine whether the desired unit costs can be obtained. At the same time determine whether certain records currently being kept are actually useless and should be eliminated.

4. Supply cost information to all water works personnel who can assist in controlling costs. The efficiency of operations, including theirs, is measurable by the costs of performance. Some records, such as automobile costs, should be posted for all to see.

5. Keep cost information on a current basis. Old records are good only for comparisons with current data.

6. Decide to spend enough time on cost control so that it may become a useful management tool, to the end that expenses may be reduced and net income increased.

Reference

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Remote Pump and Valve Controls

By Leslie Paul

A paper presented on Oct. 30, 1952, at the California Section Meeting, Pasadena, Calif., by Leslie Paul, Supervising Mech. and Elec. Engr., East Bay Municipal Utility Dist., Oakland, Calif.

THE East Bay Municipal Utility Dist. is the principal water supply agency for ten cities and a large unincorporated area on the east side of San Francisco Bay. The area served is more than 200 sq miles in extent with a total population well in excess of 900,000.

The average consumption at present is approximately 113 mgd, of which approximately 35 mgd must be pumped from an elevation of 250 ft to elevations varying up to 1,552 ft. As a large portion of the area served is broken, mountainous terrain, the water must be lifted through 67 distribution pumping plants, in which the pumping units range from 1.5 to 500 hp. Each of the two largest distribution plants have two units, each unit being capable of lifting 3,400 gpm through a total dynamic head of 525 ft. The total connected load of the distribution pumping plants is 10,800 hp.

The district also has four transmission pumping plants with a total connected load of 14,950 hp, the largest plant having two 4,000-hp units. At present, the transmission pumping plants are out of operation and are maintained for emergency or standby purposes only. In connection with its filter plants, the district also operates six auxiliary pumping plants totaling 475 hp.

Altogether, there are 77 pumping plants with a connected load of 26,205 hp. Of these, the distribution pumping plants are of most interest because they include the greatest variety of automatic operating features.

Early Installations

The first automatic pumping plants were controlled through float switches at the tanks being served by the pumps. In time most of the float switches were replaced by 0–15-psi pressure switches installed in the inlet pipe to the tanks. The pressure switches cost less than half as much as float switches, required no float pipes or guide wires inside the tank, and were more accessible than float switches.

A disadvantage of the pressure switch lay in the fact that it was slightly less accurate in setting because of the velocity head in the main entering the tanks where the pressure switch had to be installed, but it was accurate enough to be practical.

Another difficulty, common to both types of switches, especially those installed in outlying areas, occurred when small spiders entered the enclosures of the switches, spun webs, completed their life cycle, and died. Ants would then enter to eat the remains, often causing shorts across the small switch terminals or so plugging up the small

contact mechanisms that the switches could not operate.

In the earlier installations, these float or pressure switches were connected to the control circuit of the motor starters through a pair of wires hung in trees or installed on crude pole lines. Most installations were in the outlying service areas, where efforts to economize introduced hazards and imposed an excessive amount of maintenance work. Pole lines were expensive; it was difficult to obtain rights of way for them; and district participation in a "joint pole agreement" with other utilities met with legal obstacles.

Some of these difficulties were surmounted by laying No. 14 duplex parkway cable in the trench when installing a pipeline between a tank and a pumping plant. This method served fairly well, but it had its disadvantages. It was expensive; it was often broken by sewer contractors and by other utilities installing their own facilities; and the armor on the outside of the cable ultimately succumbed to electrolytic corrosion. Efforts to economize during the depression led to the substitution of trenchlay for parkway cable. Like parkway cable, this was a lead-covered cable with a protective covering of jute on the outside, but, unlike parkway, it had no steel armor outside the jute. When found by the laborers of contractors and other utilities, it was frequently mistaken for tree roots and chopped away.

Plastic insulated wire, when first introduced during the WPA days of the depression, was recommended by the manufacturer as the best material yet

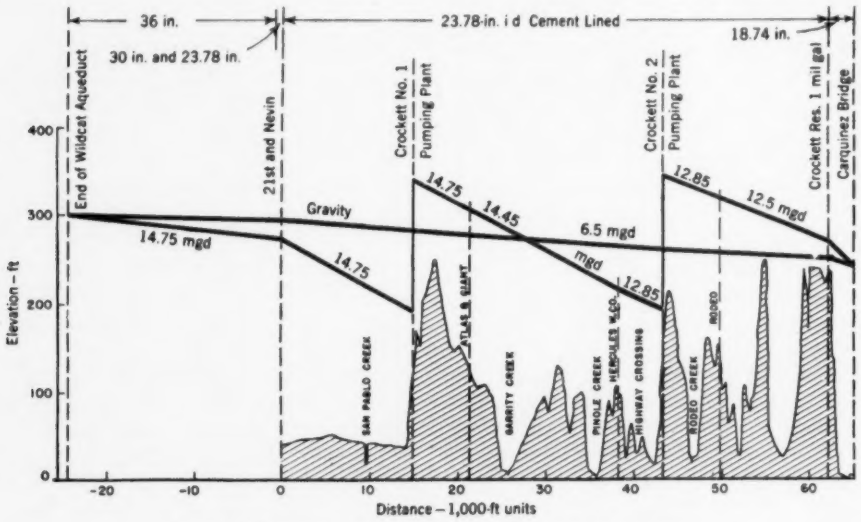

Fig. 1. Hydraulic Characteristics of Crockett Pipeline

Remote-control equipment maintains the desired water level in Crockett Reservoir by activating the pumps in Plant No. 1 and, if necessary, in Plant No. 2. The distance shown on the horizontal scale is measured from 21st Street and Nevin Avenue.

developed for buried signal lines. This material was tried out on one job and was strung along in the trench with the pipe. Unfortunately, the trench had been cut through rocky material and the plastic wire was promptly chopped to pieces by the broken-rock backfill and by the sharp edge of the round-nose shovels used for placing and tamping the backfill.

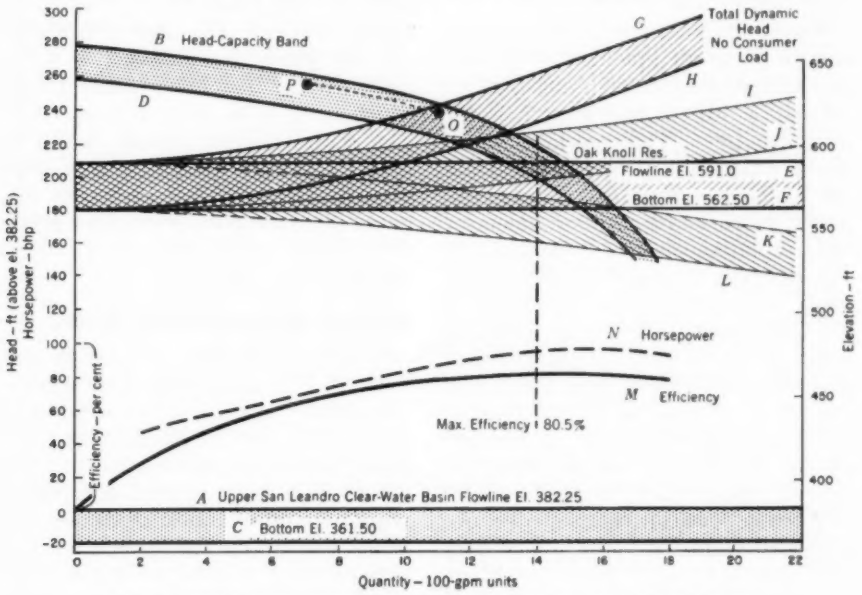

Fig. 2. Centrifugal Pump Characteristic Curves—Oak Knoll Plant

Lines A *and* C *show flowline and bottom elevations for the clear-water basin. Lines* E *and* F *show these elevations for Oak Knoll Reservoir. The bands formed by the characteristic curves reflect the water level conditions in the reservoirs. The left-hand ordinate scale applies to head, efficiency, and horsepower, the head being measured in feet above the flowline elevation of the San Leandro Basin; the efficiency, in per cent; and the horsepower, as brake horsepower (bhp).*

Telephone Signal Channel Controls

The troubles connected with buried signal lines brought about the use of leased telephone lines by the district. These were partially satisfactory and the district still has seventeen in use for various control purposes. Leased signal channels are comparatively expensive, however, and are subject to interference from telephone company employees who, for test purposes, occasionally open the circuits at the telephone exchanges or on pole lines in rural areas, thus deenergizing the holding coils in the various control devices and shutting down operations. Also, dust collecting on the line insulators during the summer absorbs fog and dew in the early fall, causing current leakage to the ground. This condition lasts until the first rains wash off the

insulators. In the interest of safety, the telephone company limits direct current to 135 v line to ground and 270 v line to line. If alternating current is used, it must not exceed 120 v line to ground or line to line, and the frequency must be limited to 15 cycles per second. These restrictions necessitate another relay step in control circuits.

Figure 1 shows the pipeline profile and the hydraulic gradients of the district's most spectacular installation involving a leased telephone line for pump control. This pipeline, which serves water to the city of Vallejo and the California Hawaiian Sugar Refinery, has a 23.78-in. inside diameter and is approximately 12 miles long. It was designed for a gravity flow of 6.5 mgd, but, owing to the expansion of war industries, two booster pumping plants in series, each pumping around dividing check valves, were inserted in the line to increase the flow to 15 mgd. A telemetering transmitter on the roof of the 1-mil gal Crockett Reservoir emits a signal which records the reservoir water level on charts in the two pumping plants and the supervisory station at the San Pablo Filter Plant. If gravity flow will not supply the load and the water level in the tank falls, a mercury switch attached to the pen arm shaft of the telemeter water level receiver in Plant No. 1 starts three pumps in sequence, controlled through a rotary-cam selector switch. This switch was designed and developed by J. O. Harvey, a district employee. If the water level in the reservoir continues to fall, identical equipment starts the pumps in Plant No. 2. These pumps operate until the water level is restored to a given elevation in the reservoir, at which time a mercury switch in the telemeter receiver of Plant No. 2 takes the pumps off the line. When the reservoir is again full, the pumps in Plant No. 1, as in Plant No. 2, are shut down in the reverse order of starting, and the system returns to gravity flow.

The distance between Plant No. 2 and the reservoir is approximately 3 miles, while the distance between the reservoir and Plant No. 1 is approximately 7 miles. The same circuit carries the water level message to a recorder at the San Pablo Filter Plant, which is 17 miles from the reservoir. The control signal channel, however, takes a longer, roundabout course through five telephone exchanges between the reservoir and the filter plant. This system, in operation for 9 years, has been very successful.

Controls Without Signal Lines

There has long been a desire to find some way of controlling pump operation without the use of wires between the reservoir and the pump. The automatic control systems now used by the district have been evolved over many years. At present most of the smaller plants operate on the "time-start and pressure-stop" system, while the larger plants, pumping to the larger reservoirs, where it is impractical to install altitude valves, operate on the "time-start" and "time-stop" system. The latter requires only the inclusion of a time switch in the control circuit of the motor. For the conditions existing at these plants, time switch control is entirely satisfactory. The former system requires a time switch and a pressure switch in the control circuit of each motor, an altitude valve at the tank or reservoir, and a pump with a fairly steep head-capacity curve. This system has been used by the district for approximately 12 years and is coming

into more general use by others. Its application in district design and operating practice is unique, however.

Figure 2 shows the three typical characteristic curves for a centrifugal pump: head-capacity, brake horsepower–capacity and efficiency-capacity. For best results, the head-capacity curve should be fairly steep with a rising characteristic. As illustration, the author has selected a typical set of curves from the Oak Knoll Pumping Plant.

Line *A* is the baseline to which everything on the rest of the chart is referred. As the normal condition of a good distribution system reservoir is full, Line *A* represents the flowline of Upper San Leandro Clear-Water Basin, from which the water is being pumped. The line also represents the abscissa for the graph and is divided into 100-gpm intervals. The flowline (*A*) is taken as the zero point for the ordinate scales on the left side of the graph. The ordinate scale showing head in feet above el 382.25 (the clear-water basin flowline) is used for plotting Curve *B*, the head-capacity curve of the pump. Because the clear-water basin may not always be full, however, the plot of the head-capacity curve is repeated as Curve *D*, which is referred to the bottom of the clear-water basin (Line *C*). Thus, the head-capacity curve is not a single curve, but a family of curves represented by a broad band which is related to another broad band based on the reservoir water level.

The pump is lifting water to Oak Knoll Reservoir with a flowline represented by Line *E* and a bottom elevation represented by Line *F*. The intersection of this band and Band *BD* fixes the limits of the varying static head, because the pump may have to lift water from a nearly full reservoir to a nearly empty reservoir or from a nearly empty reservoir to a nearly full reservoir.

In addition, the pump must also overcome the friction head of the piping system between the lower and upper reservoirs, and, when this is superimposed on the static-head band, another band, bounded by the exponential curves *G* and *H*, is derived. This band, referred to Band *AC*, represents the total dynamic head with no consumer load against which the pump must work. As the consumer load increases, Band *GH* tends to bend down to approximate Band *IJ*. If the pump is delivering more than the consumer load, some water will flow into the reservoir, but if the consumer load is greater than the capacity of the pump, Curve *GH* will bend down to approximate Band *KL*, because water is coming from both the reservoir and the pump to satisfy the consumer load.

There is thus established an open-system operating area for the pump, bounded by curves *B*, *D*, *G*, and *L*. The first three of these curves represent limiting values definitely fixed by the physical characteristics of the pump, the elevation of the water in the reservoirs, and the characteristics of the pipe system. The fourth side of the area, bounded by Curve *L*, remains a variable and is a function of the consumer load, changing from moment to moment.

It should be noted that this operating area covers the top and most favorable part of the efficiency curve, *M*, and that the 100-hp motor is not overloaded at any point, as shown by Curve *N*.

Suppose now that the heavy consumer load for the day has tapered off, the reservoirs are nearly full, and the operating point of the pump has reached

Point *O* when Oak Knoll Reservoir fills and the altitude valve begins to close. A transition from pumping into an open system to pumping into a partially closed system is now imposed on the pump, and the operating point, *O*, begins to move up and out of the open system area toward Point *P*. At *P*, a pressure switch in the pumping plant opens, deenergizing the holding coils in the control circuit of the motor, and the pump stops. As soon as the pressure on the reservoir side of the altitude valve becomes greater than that on the pipeline side, the altitude valve opens and the reservoir satisfies the call of the system for water until the next cycle of operation.

In some automatic pumping systems in which the piping grid is not very well developed, starting and stopping pumps against open valves may introduce water hammer problems. In this situation, slow-opening and slow-closing, solenoid-controlled, hydraulically operated valves (with quick-closing features for protection against reversal of flow due to power failure) have given very satisfactory results. The pressure switch operates the four-way solenoid valve, causing it to close, and a time delay relay opens the pump control circuit when the valve is closed or a limit switch on the valve opens the circuit when the valve is nearly in the closed position. The time switch for activating a pump equipped in this manner starts the pump and causes the four-way solenoid valve to begin opening the main control valve at the same instant.

If pressure disturbances—such as the too rapid closing of altitude valves, pressure regulators, fire hydrant valves, processing valves in a consumer's establishment, or blowoff valves or gate valves in the grid system—might interfere with the proper functioning of pressure switch devices, their smooth operation can be assured by including a small air dome, approximately 18 in. long and 1½ in. in diameter, in the pressure lead to the switch.

There are many pressure limit and time switches and time delay relays on the market which are applicable to this type of control. The time switches vary from the ordinary three start and stop per day type to the fancy program clocks which allow starts and stops every few minutes. Pneumatic time delay relays are best for use in this application. There are several good electric pump control valves on the market with all of the pilot controls built into the valve assembly.

Control Valves

Conditions at some points in the district distribution system have warranted the installation of rate-setting valves remotely controlled from central dispatching points, such as filter plants. At present the district has five of these valves, all operated by three-phase motors which can be pushbutton-operated at the valve, as well as from the remote control station.

A typical installation is the Genoa Street valve station, which was the first of this kind installed by the district. The main features of this station are a venturi tube and telemetering register, a 30-in. lubricated plug valve, and a leased telephone signal channel between the Orinda Filter Plant and the valve station. The signal channel serves four purposes: it transmits through the telemetering device the flow rate in the pipeline, indicates valve position, opens the valve, and closes it. If it is desired to increase the rate of flow, the

operator at the filter plant, which is approximately 10 miles away, pushes a button marked "open." This operates two relay systems, one of which temporarily takes the flow rate telemetering equipment out of service, while the other, which is connected into the control circuit on the valve motor, causes the valve to open through an arc of 5 deg. At this point, the valve control circuit is disconnected and the telemetering circuit is reconnected, requiring the operator to wait until he can get a reading on the chart register before pressing the button for another turn of 5 deg or less, as required. This control system, originated by William A. LaViolette (*1, 2*) of the Pacific Gas and Electric Co., for use on its high-pressure gas lines, has been modified for district use. Operators of high-pressure gas lines must contend with Charles' and Boyle's laws. Likewise, operators of high-pressure water lines must contend with the incompressibility of water and attendant water hammer phenomena. The feature of limiting the valve travel to 5 deg came about through experience which revealed that operators on duty sometimes became nervous and, in panic, would fail to synchronize flow rate properly with valve positioning. Limiting the valve travel imposes a waiting period which allows the system to become stabilized so that a good flow chart reading can be obtained before pushing the button again for further opening or closing. Valve travel limitation also reduced to a minimum the generation of water hammer surges in the pipeline. This limiting feature is used on all of the other supervisory control valves in the district. In addition, it is necessary for the operator to hold his finger on the button to obtain a response from the valve motor.

Another installation, the 82nd Avenue rate control valve, has the same system of control as the Genoa Street valve, except that the venturi telemetering system is separate from the valve control, because the venturi meter is in a different location from the valve. This installation has a 30-in. rotating plug which is mechanically jacked from its seat before turning. The valve is controlled at the Upper San Leandro Filter Plant, from which water flows to the valve.

A third installation, with a 36-in. valve of the type used at 82nd Avenue, is the raw-water control valve at the San Pablo Filter Plant. The distance between the valve and the control cabinet in the filter plant head house is only 600 ft, and the telemeter and valve control circuits are separate. As this is not a leased telephone line, the control circuit is alternating current and the pushbuttons directly energize the holding coils of the reversing motor starter. A selsyn motor system indicates the position of the valve and has its own circuit.

The Leland rate control valve system, which is not yet complete, is a duplicate of the 82nd Avenue system, except that a 24-in. lubricated plug valve will be used. This valve will be controlled from the new Lafayette Filter Plant.

The Central Reservoir control valve system is essentially the same as the Genoa valve installation, except that the valve used is a 16-in. ball valve. This valve is also controlled from the Orinda Filter Plant, which is approximately 13 miles away. The single signal channel will have an extra burden to carry, however, as it will not only

have to control the opening and closing of the valve and record the venturi meter flow, but will also have to record, on the same chart at the Orinda Filter Plant, the water level in the 158-mil gal Central Reservoir. This will be done by polarizing circuits and alternately receiving the venturi meter message for 75 min and the water level message for 15 min. Flow is favored in this way because the water level will not change valve, both the flow and water level telemeters will be temporarily taken out of service until the new rate is set.

During early work with leased telephone signal channels, some difficulty was experienced in making adjustments on newly installed equipment because of the great distance between the transmitting and receiving apparatus. This trouble was soon overcome through the use of a pair of U.S. Army field telephone sets. By connecting the telephones at both ends of a leased line, vocal communication could be established between the transmitting and receiving stations, and much time lost in travel back and forth between the two stations was eliminated. Ordinarily, the telephone companies forbid private equipment to be connected to their facilities, but connections of this kind made for maintenance and adjustment purposes are not prohibited if they are temporary or occasional and if the spoken messages are terse and confined to the particular apparatus under adjustment.

The successful operation and the economies effected by these automatic and supervisory facilities warrant their expanded use as the East Bay Municipal Utility Dist. continues to extend its service area.

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Instrumentation in the Laboratory

By Jack H. Wyatt

A paper presented on Oct. 30, 1952, at the California Section Meeting, Pasadena, Calif., by Jack H. Wyatt, Assoc. Public Health Chemist, Div. of Water Resources, Sacramento, Calif.

A QUANTITATIVE analysis comprises five operations:

1. Sampling to secure a known amount of representative material.
2. Separation of the substance to be measured from interfering substances.
3. Conversion to a form suitable for measurement.
4. Measurement of a property which bears a known relationship to the amount or concentration of the desired substance in the sample.
5. Calculation of the concentration from the observed data.

Instrumentation is concerned principally with the measurement step—in the older procedures, measurement of mass or volume. The buret is inexpensive and sufficiently accurate for most purposes. The analytical balance is a marvelously accurate instrument; it is not unduly difficult to perform measurements reproducible to 1 part in 1,000,000 on any good balance. Unfortunately, this high instrumental accuracy has fostered a greatly exaggerated idea of the accuracy of gravimetric methods in general. Most gravimetric and many volumetric methods require precipitation, a rather inaccurate operation. This and other errors in the methods are the limiting factors in accuracy and are responsible for the fact that, even using an instrument capable of 1 : 1,000,000 accuracy, actual results accurate to 3 : 1,000 are regarded as good, and the great majority of analytical results are probably not dependable to closer limits than 1 : 100. Even though the individual chemist may consider his results much better than this, collaborative studies have repeatedly demonstrated that they are not.

Because of the associated errors, as well as the large labor requirements, measurements of mass and volume are gradually being supplemented or supplanted by measurements of interaction with radiant and electrical energy. This discussion is concerned with such measurements. A number of publications listed at the end of this paper will be found valuable for general reading (*1–10*).

In evaluating any method, it is necessary to consider the following characteristics as related to the particular application: scope, mass sensitivity, concentration sensitivity, accuracy, specificity, interferences, adaptability to multiple determinations, speed, and operating and capital cost. Various instruments will be compared on this basis. Figures 1–3 show approximate graphical comparisons of certain instruments.

Radiant Energy

Radiant energy varies in wavelength and frequency from long, low-frequency radio waves through the infra-

red, visible light, and ultraviolet to the X rays and cosmic rays. It is emitted continuously by all matter, with intensities increasing greatly at higher temperatures. To secure intensities useful for analytical purposes, special sources are used, consisting, in the most useful analytical region, of heated matter.

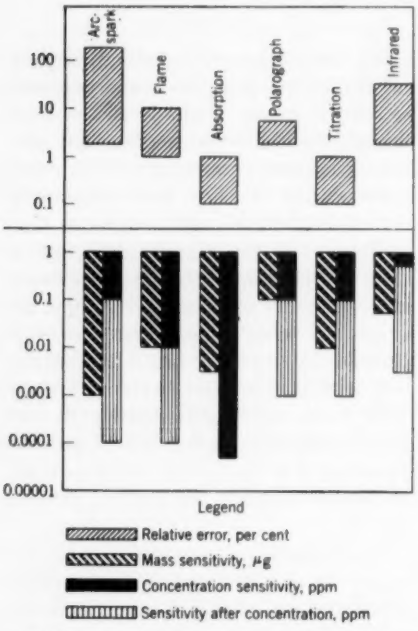

Fig. 1. Instrument Sensitivities and Accuracies

The scale at left applies to all characteristics shown, with the units as indicated in the legend.

Radiation is of two types—continuous and discontinuous. Continuous radiation ordinarily is produced by a heated solid, such as the filament of an incandescent lamp. Discontinuous radiation is produced by heating gaseous material to a high temperature or subjecting it to an electrical discharge, or both. It produces a spectrum consisting of lines or bands characteristic of the emitting substance.

Radiation is usually separated into components of various wavelengths before measuring. This separation, called dispersion, may be accomplished in several ways, which differ greatly in cost and in narrowness of separated wavelength band, and hence in resolution. The simplest and least expensive is the light-absorption filter, which costs approximately $6.00. It has a half-width of about 60 mμ (1 millimicron = 10^{-9} meter) and a total width of significant intensity of approximately 120 mμ. The interference filter, costing about $25, gives a considerably improved half-width, approximately 15 mμ, but only a slightly improved total width, approximately 100 mμ. It must be illuminated by parallel light. Filters are subject to the limitation that it is necessary to have a different one for each band to be used.

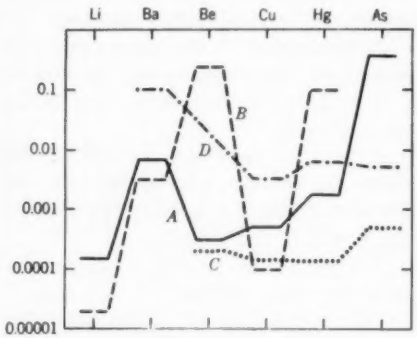

Fig. 2. Approximate Sensitivities to Selected Elements

Curve A *represents arc-spark spectrum sensitivity; Curve* B, *flame spectrum sensitivity; Curve* C, *absorption spectrum sensitivity; and Curve* D, *polarographic sensitivity in ppm in original sample. Concentration is used where applicable.*

Prisms and gratings provide greatly improved resolution at a considerable

increase in cost. The Beckman * Model B prism spectrometer has a half-width of approximately 1–10 mμ; Model DU has a half-width of approximately 0.01–10, but the band width actually usable with the DU at 500 mμ is usually approximately 2 mμ, which can be improved to 0.3 mμ if the minimum slit can be used. The resolution of grating spectrographs varies from about 0.1 mμ for the Cenco † 1 meter to 0.004 mμ or less for the very large instruments. Prism spectrographs have slightly better resolution in the extreme ultraviolet than grating instruments of comparable cost but are much poorer at longer wavelengths. Modern gratings have less scattered light than prisms but produce overlapping orders which may be troublesome in some applications. A graphical comparison of band widths for various instruments is given in Fig. 4.

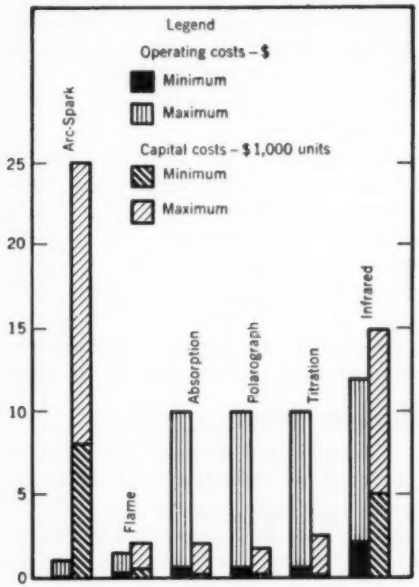

Fig. 3. Estimated Costs

The minimum and maximum operating and capital costs are compared for various instrumental methods.

Measurement of radiation may be instantaneous or integrating. Visual comparison using a neutral wedge can be as accurate as most electronic detectors (1 per cent) but is undesirable because of fatigue. Detection by amplified phototube can be extremely sensitive, but at cost of a degree of noise and instability. The Beckman and Coleman ‡ instruments and the Fisher § Nefluorophotometer use this principle. Application of the barrier layer photocell and galvanometer is limited by poorer sensitivity and narrower wavelength range than are available with a selection of phototubes, but it is probably the most stable and generally satisfactory detector within its range. This detector is used in most filter photome-

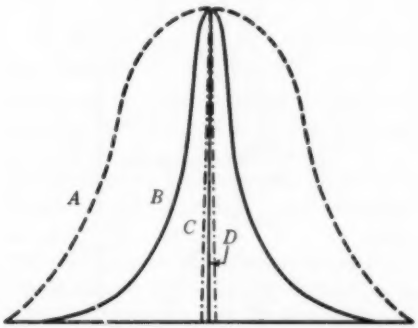

Fig. 4. Transmission Bands of Typical Instruments

A graphical comparison of band widths is shown for the following instruments: A—*color filter,* B—*interference filter,* C—*spectrophotometer, and* D—*spectrograph.*

* Beckman Instruments, Inc., South Pasadena, Calif.

†Central Scientific Co., Chicago.

‡ Coleman Instruments, Inc., Maywood, Ill.

§ Fisher Scientific Co., Pittsburgh, Pa.

ters and in the Cenco spectrophotelometer. For the infrared region beyond 2 μ these detectors are replaced by thermocouples or resistance elements, which measure the heating effect of the radiation.

For measuring the radiation from arc and spark sources, which cannot be stabilized, an integrating detector is necessary. The most familiar is the photographic film, which responds to radiation according to the relations:

$$D = \log \frac{I_0}{I_1} = f(\log E)$$

$$E \simeq \int I dt$$

in which D is the density of the developed image, I_0 is the incident light, I_1 is the transmitted light, E is the exposure, I is the intensity of light during exposure, and t is the time of exposure.

By properly standardizing conditions, it is possible practically to eliminate the error caused by the approximate relation for exposure. The value of $\int I dt$ can then be obtained from the calibration curve for f (log E), a typical example of which is shown in Fig. 5.

A more recent introduction (*11*) is the use of electronic integration by charging a capacitor with a current which is proportional to the intensity of radiation. A simplified circuit is shown in Fig. 6. The potential across C is measured by the vacuum tube and meter. This integrator is governed by the equations:

$$i = kI$$

$$e = \frac{q}{c} = \frac{1}{c} \int i dt$$

$$e = \frac{k}{c} \int I dt$$

in which i is the charging current, k is the phototube sensitivity factor, e is the capacitor potential, q is the capacitor charge, c is the capacitance, and I and t are as previously defined.

Commercial instruments using electronic integration are extremely expensive and are of value only when a few elements must be determined on routine samples with very great speed (less than 1 min on prepared metal samples). For ordinary work the photographic record is preferable because it records many elements simultaneously. Accuracy is approximately equal for the two methods.

Applications of radiant energy, whether emission, absorption, or Raman spectra, are mostly based on a single property of substances: the various possible transitions between thermal-energy levels within the atom or molecule. Each of the various types of measurement is, however, particularly adapted to a certain type of analysis.

Emission Spectra

The analytical emission spectrum is produced by dispersing the radiation emitted at high temperature (1,000°–6,000°C) or in an electrical discharge by the vaporized sample. It consists mostly of element lines but with a few molecular bands. Partly because of instrumental limitations, it is most useful in the range 2,000–8,000 A. Three methods of excitation are in common use: flame; the low-voltage, high-current arc; and the high-voltage condenser discharge spark.

Emission methods, in general, have a very wide scope; all elements can be determined by their use. The mass sensitivity is good for most elements, but concentration sensitivity is poorer because very small samples are used.

Interferences are very serious limitations on accuracy, but in routine work it is possible to compensate or correct for them. Both the separation and the conversion step can usually be omitted.

The flame spectrum is restricted in scope, as some elements give very weak spectra or none at all. Its sensitivity is very good for the alkalis and alkaline earths, and sufficient for some easily excited heavy metals after concentration. Very good accuracy is possible with high-grade instruments and proper

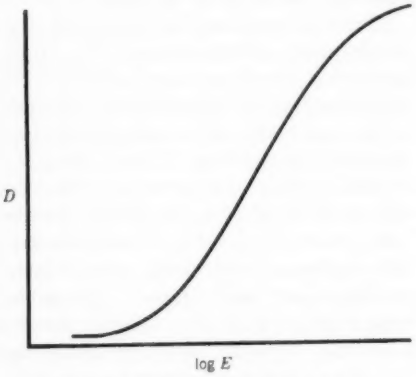

Fig. 5. Film Calibration Curve

D *is the density of the developed image, and* E *is the exposure.*

correction for interferences. Provided that moderately good resolution is available, specificity is good because of the simple spectrum.

Present flame spectrometers are not adaptable to multiple determinations, but it is possible to assemble from available parts an instrument which will either produce a photographic record or give simultaneous readings on several lines. Speed of analysis is excellent; only seconds are required to introduce the sample and make a reading. A substantial part of the labor involved is expended in setting up and calibrating the instrument and in making corrections for interferences if very accurate results are desired on widely varying samples. The operating cost is low and the capital cost varies between $500 and $2,000. For determination of sodium and potassium, simple absorption or interference filter instruments are usually satisfactory.

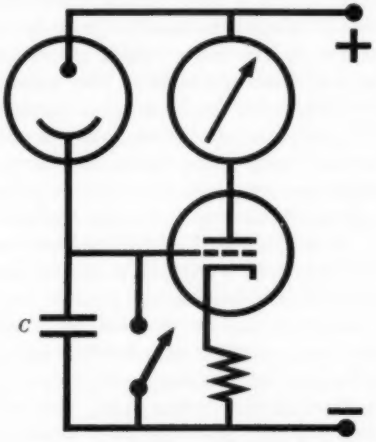

Fig. 6. Electronic Integrator

A simplified circuit is shown. The capacitor is charged with a current proportional to the intensity of radiation. The potential across C *is measured by vacuum tube and meter.*

The flame spectrum is used by the California Div. of Water Resources in the determination of sodium and potassium, for which it provides the only simple and dependable method. It is also useful for the detection of the rare alkalis and can be used for the easily excited heavy metals, after concentration, if the arc spectrum is not available. The sensitivities indicated in Fig. 1 and 2 are based on evaporation to 0.01 volume. With present instru-

ments and methods, the advantage of the flame spectrum over the volumetric method for calcium and magnesium is questionable, because interferences make the results inaccurate unless preliminary separations are made.

The arc and spark spectra are applicable to all elements, although not always with good sensitivity. Nearly all metals are readily determined with either, but the semimetallic and nonmetallic elements usually give better spectra in the high-voltage spark or gaseous discharge tube. The volatile elements, such as mercury, arsenic, lead, and zinc, ordinarily are not determined with good sensitivity in the carbon arc or spark because they are evaporated too soon. The sensitivities shown in Fig. 1 and 2 are based on evaporation to dryness of a sample containing 1,000 ppm solids.

Accuracy can be as good as 2:100 with very careful standardization of techniques in routine work, but usually is much poorer than this. For nonroutine work, an error of a factor of two or three is generally regarded as good. Stability and accuracy are somewhat better for the high-voltage arc or spark than for the low-voltage arc.

The specificity depends on the nature of the sample matrix and the resolution available. For matrices giving simple spectra, medium resolution suffices to give specific results, but in matrices such as iron, cobalt, and molybdenum, which have complex spectra, it is necessary to have high resolution to prevent masking of traces by lines of the matrix.

One of the greatest advantages of the spectrograph used for arc and spark work is that it records at one time all of the elements which are within its scope under the particular conditions of excitation. It is possible to determine nearly all of the metals and some of the semimetallic elements from one or two spectrograms. Although exposure and development of the photographic record takes a little longer than the flame test for a single element, it affords a saving in time and cost if several elements must be determined. The capital cost of medium-dispersion spectrographic equipment is $8,000 or more, but the expenditure is justified if a substantial amount of work is to be done.

The arc spectrum is useful for the simultaneous determination of a large number of metals in water after evaporation to dryness, although for several of the common toxic elements the sensitivity is insufficient. Those elements of particular interest for which the sensitivity is good are aluminum, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, and nickel. Available data indicate that the volatile metals, antimony, bismuth, mercury, thallium, and zinc, should be determinable with good sensitivity under proper conditions, although it may be necessary to separate them from sodium, calcium, and magnesium, which seriously repress certain lines. The Los Angeles Dept. of Water and Power is one of the few organizations which has had extensive experience in spectrographic analysis of water.

Absorption Spectra

Absorption spectra may be obtained by passing continuous radiation through solids, liquids, or gases. The absorption spectrum of a substance will be the same as the emission spectrum except that the light and dark segments will be reversed. It is, however, im-

practical to measure the absorption spectrum of free atoms except in the radiation from the stars, where a sufficient concentration of atoms has been provided by nature. In emission spectrography, this absorption appears as annoying self-absorption, which decreases the intensity of lines and lessens accuracy.

Molecular absorption in the vapor phase provides a very useful spectrum of narrow absorption bands, which has been of great value in determining molecular structure. It is used also for control of vapor-phase operations in the organic-chemical industries. Solid-phase absorption is generally not used unless no suitable solvent is available for the material to be examined. In liquid samples, on which most absorption measurements are made, the absorption bands are greatly widened by the attraction of nearby solvent molecules, which alters the magnitude of the various energy transitions. Resolution is limited by the breadth of the absorption bands.

The absorption of most ions in the visible and ultraviolet region is too weak to be useful for the determination of small concentrations. It is necessary to convert the desired ion into a strongly absorbing compound. Desirable properties of absorbing materials include: stability; independence of concentration of hydrogen and other ions; linear absorption; absorption peak within the visual range for easiest measurement and control; and low temperature coefficient. Desirable characteristics of reaction are: rapid development; nonabsorbing reagents; quantitative reaction; known mechanism; order and manner of reagent addition not critical; simplicity of manipulation; freedom from interference; and specificity.

The value of the absorption spectrum obviously depends upon the degree to which the available reactions meet the above requirements. Good methods are available for most elements, with the exception of the alkali and alkaline-earth metals. Absorption methods are thus complementary in scope to the flame spectrum. In contrast to emission methods, the sample can usually be reasonably large, so that the concentration sensitivity is usually better, even though the mass sensitivity is sometimes poorer. The sensitivities in Fig. 1 and 2 are for a 20-cm cell depth.

In ordinary work, the accuracy of absorption methods with good instruments is approximately 1 per cent, but by comparison techniques the instrumental error can be reduced to a very small value (*12–15*). The limiting factor is then the procedures used in preparing the sample for measurement, and the method may be as accurate as the best and most painstaking volumetric or gravimetric analysis. The difference between two strongly absorbing solutions can be measured with greater overall accuracy than that with which many volumetric endpoints can be determined.

A few photometric reactions are specific, but most are not, necessitating special procedures or preliminary separations. Interferences may be encountered in oxidizing or reducing substances or complexing ions. On the other hand, interfering materials may be introduced deliberately to prevent reaction of unwanted substances with nonspecific reagents. It is very seldom that absorption bands in metal analysis are sufficiently well separated for independent measurement, but it is sometimes possible to determine several compounds by making a series of meas-

urements at different wavelengths and solving the resulting set of equations. Usually absorption bands are so nearly alike that this procedure is difficult and inaccurate, making it necessary to separate the various components or to prevent the reaction of some of them.

The speed and labor requirements vary through about the same range as for volumetric methods. Because of the necessity for separation and conversion steps, operating costs are usually higher than for the emission methods. The capital cost varies from $100 to $2,000, or higher for recording instruments.

Absorption photometric methods are routinely used by the California Div. of Water Resources for the determination of boron, silica, fluoride, and nitrate (*10*). These methods can also be employed to determine ammonia, nitrite, iodide, sulfide, free chlorine, cyanide, phenols, and toxic metals. Probably the most valuable single reagent is dithizone, which can be used for the group detection of seventeen metals or for their separate determination with special extraction procedures. Sandell (*6*) has an excellent section on dithizone. Absorption methods are also used for arsenic and selenium, which are not easily determined by emission methods.

For analytical work on organic compounds, the ultraviolet and visible regions have been of some value, but because separations are frequently very difficult, it is usually necessary to determine several compounds in the same solution. The great breadth of most molecular electron bands in these regions makes mixed analysis a process of questionable accuracy and dependability, except under very favorable circumstances.

The infrared region from approximately 2 to 15 μ, on the other hand, contains many narrow and well-defined bands which are associated with particular bonds or groupings in the molecule. These bands often produce results of fairly good accuracy and specificity, although they are subject to some overlapping. The individual band is not characteristic of the molecule as a whole but of a specific bond, which ordinarily produces a similar band at nearly the same wavelength if present in other compounds. The direct mass sensitivity is approximately 5,000 times poorer than that available for most metals. Also, the usable cell depth is often limited by solvent absorption, so that the concentration sensitivity may be still more unfavorable. It is usually possible, however, to concentrate the desired substance by extraction or other applicable procedures. Cost varies from approximately $5,000 for manual instruments to $12,000 or more for recording instruments.

Infrared absorption has been applied to the determination of oil and phenols in wastes, with a very great saving in labor and an improvement in accuracy and sensitivity (*16*). It is being used also for the detailed study of odor-producing substances after concentration on activated carbon (*17*).

When monochromatic radiation passes through a homogeneous solution, a part of the scattered radiation is displaced in wavelength from the original by the same energy difference as that which characterizes the infrared absorption bands. This effect produces the Raman spectrum, which is used for the same purpose as the infrared. It is included in this section for that reason, although it is not an absorption spectrum. The Raman spectrum is not

limited by solvent absorption. It is possible to apply it to solutions in water and other polar solvents which are opaque in the infrared region, but it is of less value than the infrared for water analysis because its sensitivity is too low for concentrations ordinarily encountered.

X-ray absorption is entirely different from the other absorption methods. It depends on differences in the mass of atoms and is applicable to such problems as the determination of lead in gasoline. It gives accurate results with very little labor but is entirely unspecific at present.

Other Photometric Methods

The measurement of radiation scattered by particles, if direct, is called nephelometric, and if by difference, turbidimetric. In both types, the measurement is inaccurate because of the difficulty of obtaining stable suspensions with reproducible particle size. Consequently, these methods are used only when no good method is available or when very rough values are acceptable.

Measurement of fluorescence is of some value, although available methods are comparatively few. This method suffers from the disadvantage that the exciting radiation frequently causes decomposition of the substance to be determined.

Electrical Energy

Electrical measurements are used either as direct analogs of concentration or as indicators of the equivalence point in titrations. The concentration sensitivity of titration methods rarely approaches that of the photometric methods. The mass sensitivity, however, can be made considerably more favorable by the use of the microtechniques developed by P. L. Kirk (*18*) and other workers in the field of biochemistry. By these techniques, a single drop of liquid can be titrated with the same accuracy obtained in normal volumetric analysis.

The overall accuracy of volumetric analysis varies widely. In favorable instances and with extreme precautions, it may approach 1 : 1,000, which approximates the practical limit of accuracy of very careful volumetric measurements. Usually, however, volumetric errors are considerably greater than this, and inherent errors of method and uncertainty of equivalence point increase the error to 3–10 : 1,000. The equivalence point detection may be far more accurate than the rest of the analysis in the potentiometric titration of a strong base with a strong acid, while it may be the major limitation on accuracy in the successive titration of two compounds of only moderately different dissociation constants or reaction potentials.

Potentiometric Measurements

Direct use of cell potential measurement is, in common practice, limited to the determination of hydrogen ion activity. It is extremely valuable, however, for determining the equivalence point. It can be used in all titrations involving acid-base or oxidation reactions, and in any precipitation or complex-forming reaction for which a suitable indicator electrode is available.

Potentiometric titration has four major advantages over the use of color-change indicator compounds: it is not affected by the color or turbidity of the solution; it avoids the individual error of a subjective color observation; it is readily applicable to automatic op-

eration; and it gives a continuous range of potential not limited by the availability of a succession of indicators. The last characteristic makes it possible to match the equivalence potential exactly rather than approximately and facilitates titration of two or more substances in succession in a single operation. This procedure is often inaccurate or impossible otherwise, because of the lack of suitable indicators.

Potentiometric titration is commonly used in water analysis for acidity and alkalinity because of its convenience and superior accuracy. It can also give more accurate endpoints in chloride titrations.

Polarization

Electric current flows through solutions by the movement of ions rather than electrons, and, in order for current to flow between a solution and an electrode, there must be a reduction, which removes an electron from the electrode, or an oxidation, which gives an electron to the electrode. No reduction or oxidation can take place unless the electrode potential is favorable to the reaction, and the rate of the reaction —and, hence, of the current—is limited by the rate at which the ion involved diffuses toward the electrode.

In the polarographic cell, the indicator electrode is made small in comparison with the reference electrode, and a relatively high concentration of salts is added to decrease the resistance of the solution. Because of the large area and small current density, the potential of the reference electrode is substantially constant and equal to the open-circuit potential. The potential drop across the high-conductance solution is practically zero. The microelectrode, however, is polarized by depletion of active ions near its surface, and the current is proportional to the rate of diffusion to the electrode, which in turn is proportional to the concentration of reducible ions. If the potential is gradually increased, an abrupt increase of current occurs at the potential which suffices to reduce an ion of the solution. The potential at which this increase occurs serves to identify the ion, while the magnitude of the current is proportional to the concentration.

The scope of polarographic analysis includes all metals, most nonmetallic elements, and many inorganic and organic compounds. Many determinations, however, involve difficulties which make polarographic analysis impractical. It is actually or potentially valuable in the determination of heavy metals, semimetallic elements, oxygen, free chlorine, and certain reducible organic compounds.

The polarograph is unique in that the molar sensitivity is of the same order of magnitude for most substances which can be determined. A typical dropping mercury electrode gives a diffusion current of approximately 6μa for a solution containing 0.001M of a reducible metal ion. The sensitivity is far short of that obtained in spectrometric measurements, being approximately $10^{-5}M$, or 0.5 ppm for most common heavy metals; and the mass sensitivity using microcells is approximately 0.5 μg, making concentration necessary for trace analysis. Figures 1 and 2 are based on evaporation to 0.01 volume. The accuracy is approximately 3 : 100.

The measurement is not specific for any one substance but can frequently differentiate among several substances after other interfering materials have been removed. As many as six ele-

ments have been recorded on a single polarogram under very favorable conditions. The time and labor requirements are about the same as for absorption photometric or volumetric methods. Manual equipment is very simple and comparatively inexpensive; only a sensitive galvanometer and a few inexpensive electrical parts are required to assemble apparatus which will easily duplicate the work of the finest instruments. The cost will vary from $50 to $150, depending on the sensitivity desired. If considerable work requiring complete curves is to be done, however, a recording instrument costing approximately $1,700 is desirable.

The polarograph is potentially useful in water analysis for group detection of those elements which are not easily determined spectrometrically. These include the arsenic and selenium groups and the volatile toxic metals, cadmium, lead, mercury, thallium, and zinc. The greatest use of this technique, however, is for the determination of oxygen (*19, 20*). It is definitely superior to the Winkler method, being unaffected by most interfering substances. It offers the further possibility of greatly reducing the number of bottles required in biochemical oxygen demand rate studies by permitting repeated measurements on the same bottle.

Amperometric titration is the application of the diffusion current measurement to the determination of the equivalence point. If the current is plotted against the quantity of reagent added, the curve will show a more or less abrupt change of direction at the equivalence point. In favorable instances, results can be as accurate as with potentiometric measurement. This method is often applicable when no suitable potentiometric indicator electrode is available. The amperometric method is less convenient than the potentiometric because it is usually not possible to eliminate the plotting of titration curves.

Amperometric titration provides an improved method for determining the various chlorine compounds formed when water is chlorinated (*21*). This information is important because the compounds differ in oxidation potential and therefore in their effect on oxidizable materials and organisms in the water. Amperometric methods can be used to determine sulfate by titration with lead or barium (*9*). Accuracy is about the same as for the gravimetric procedure, but the amperometric methods which have been used do not result in any saving of labor. Some additional work is needed to determine whether the rotating electrode can be used to reduce the time requirement while retaining accuracy. There is also the possibility of applying this method to ethylenediaminetetraacetic acid titrations of calcium and magnesium by the use of a reducible indicator ion.

Conductance

The measurement of conductance of alternating current is practically free from polarization effect and provides a very rough indication of the total ionic concentration of the solution. The measurement can be used for accurate equivalence point indication in some titrations. It does not work well in solutions containing high concentrations of unreacting ions, because the relative conductivity changes are too small, and it is not generally satisfactory for precipitation reactions, which tend to coat the electrodes. A method using high-frequency current and ex-

ternal electrodes with the solution cell between them avoids the difficulty of electrode contamination but is still subject to the limitation of ionic concentration (*22*). The curves obtained from conductometric titrations are very similar to those from the amperometric method, and the same comments are applicable.

Conductometric titration, especially the high-frequency method, is indicated as a possible procedure for the determination of sulfate with barium and of calcium and magnesium with ethylenediaminetetraacetic acid.

Coulometric Titration

The principle of the coulometric titration has been known for many years; in fact, it has been used inversely to define the unit of current by the rate of electrodeposition. Recently this principle has been employed to determine the concentration of a substance by measuring the time required for its reaction to be brought to completion by a constant known current (*23–25*). The electrolysis may take place in the solution being measured or in an external system from which the generated reagent flows into the sample container. The endpoint may be determined in any of the ways used for volumetric titrations or by noting the change in potential or current at the electrolyzing electrodes. The greatest value of the method lies in its ability to generate reagents which are not sufficiently stable to be used as standard solutions. It has the further advantage of eliminating the labor of preparing standards. The method has not been used extensively up to the present.

Automatic Measurements

Recently several types of automatic analytical instruments have become commercially available. Probably the most generally useful of these for routine work is the potentiometric titrator which stops the titration at a preselected electrode potential. Special arrangements are provided to prevent overrunning the endpoint. This instrument can result in a substantial saving of labor if a large number of titrations is performed. Either the Beckman or the Coleman instrument, with provision for two different electrode setups, will cost between $700 and $800 and can be used also for ordinary potential measurements, replacing a laboratory pH electrometer.

For work of a more diversified nature, a recording titrator is desirable. This instrument records a complete curve of electrode potential against volume of reagent and is preferable when there is a possibility of more than one reacting substance, when the potential break is not sharp, or when the equivalence potential is not known because of uncontrolled variations in the solution. The cost of the commercial instrument is approximately $2,500. These automatic potentiometric titrators save much labor in the determination of acid, alkali, chloride, and other ions which are determined volumetrically.

A very simple and comparatively inexpensive automatic titrator operates on the so-called "dead-stop" principle, which, though developed from and mechanically similar to the potentiometric measurement, is actually an amperometric titration. It is based on the depolarization or polarization of an electrode by excess titrating reagent. Titrators of this type require a very sharp equivalence point break to be accurate; titrations having considerable curvature at the equivalence point, such as is often met in precipitation reactions, require

plotting of titration curves. The principal application of this instrument has been in iodimetric determinations, especially in nonaqueous media.

Continuous Recorders

It is often necessary or desirable to provide a continuous record of a property of a stream. Any instrument which furnishes an electrical output can be coupled to a recorder to produce such a record. Single-channel recorders are available from approximately $250 and can be ganged to provide multiple records. Other recorders, designed to provide multiple records by alternately printed symbols, cost approximately $700 or more. Sometimes intermediate amplifiers, costing approximately $200 to $400, may be necessary to couple the measuring instrument to the recorder.

Properties which can be recorded without the necessity for unusual and expensive measuring instruments include temperature, oxygen, conductance, pH, residual chlorine, and turbidity. If a mechanism for continuous addition of reagents is provided, it is possible to record any direct colorimetric reaction which does not require separations, and a servomechanism to provide controlled addition of a standard solution permits recording of most volumetric titrations. Commercial recorders designed specifically for recording a particular property are available and may be more desirable for routine plant control than the more versatile arrangements previously described.

Equipment for Small Laboratory

It is obviously not feasible for the small laboratory to have all the instruments discussed in this paper. Nevertheless, it is quite possible to provide, within a limited budget, instruments which will enable the work to be carried out accurately and efficiently, if sufficient effort is devoted to getting the greatest range of utility from each item purchased.

In water analysis four types of spectrometric instruments are desirable: emission spectrograph, multiple-reading flame spectrometer, visible and ultraviolet absorption spectrometer, and infrared absorption spectrometer. At present the cost of infrared instruments is too high for most small laboratories, but the other functions can all be provided at a reasonable cost. The necessary components include:

Small grating spectrograph	$600
Spectrograph accessories	400
Alternating-current arc source (high-voltage transformer, variable transformer, voltmeter, ammeter)	300
Hydrogen burner and pressure regulators	400
Multiplier photometer with switch and 5 phototubes *	450
Ultraviolet source and silica cells	325
Incandescent source	50
Absorption cells, cell housing, exit slits (constructed to fit the needs of the laboratory)	200
Total	$2,725

* It will probably be necessary to substitute ordinary phototubes for some units in order to utilize the red lines.

This equipment will provide arc spectra, flame spectra, and absorption spectra either photographically recorded or electronically indicated. It will provide, also, simultaneous determination of sodium, potassium, calcium, magnesium, and boron by flame spectrometry. The arc spectrum will be low dispersion, not suitable for work in the presence of large concentrations of iron, and with a sensitivity sufficient for analyzing wastes but somewhat less

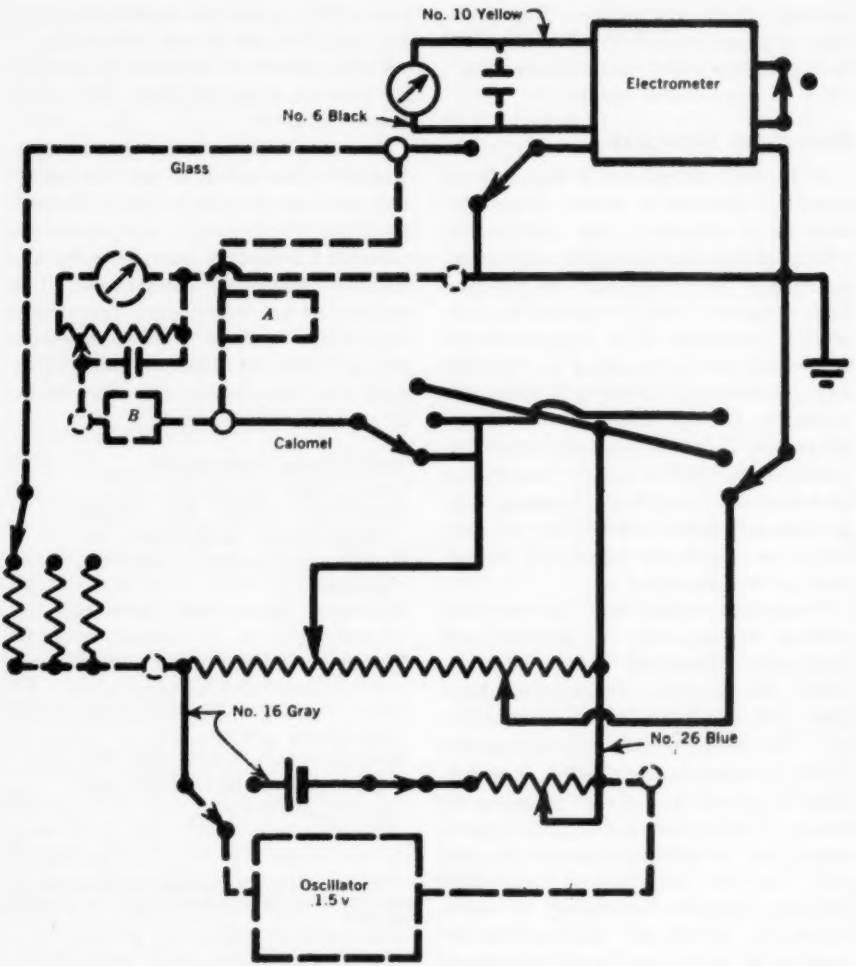

Fig. 7. Universal Electrometer

A simplified circuit is shown. The solid line represents Beckman Model G units, with the broken line indicating added units. A *is a conductance cell and* B *a polarograph cell.*

than is desirable for water supplies. The other functions will be substantially equivalent to those of the commercial spectrophotometers but with greater versatility. Some laboratories may not have need for the arc spectrum or the ultraviolet absorption spectrum, thereby reducing the cost by approximately $900. A qualified technician will be needed to assemble, calibrate, and operate these units, but the requirements are not significantly greater than those for operating any instrument laboratory.

The water laboratory is frequently required to determine the turbidity of water samples. To the author's knowledge, no commercial turbidimeter can be recommended because they are all dependent on a reference standard which has been prepared by a purely subjective method. There is need for a simple instrument which will give an absolute measurement of turbidity independent of colored substances in solution.

For routine absorption measurements, a filter-barrier cell photometer is usually more desirable than a spectrophotometer. The balancing type, such as the Klett-Summerson,* is recommended for general use, but for maximum sensitivity the Lumetron † Nessler tube photometer may be preferable. It would be possible also to build a provision for this type of measurement into the absolute turbidimeter mentioned above.

Cell potential, current, and conductance can be measured by a combination of Wheatstone bridge, vacuum tube electrometer, galvanometer, and oscillator. No commercial instrument combines all of these units, but they can be assembled from the following commercially available instruments:

Balancing pH electrometer ‡	$320
Galvanometer and shunt	140
Oscillator, 1,000 cycle, 1.5-v output	50
Damping capacitor, reference resistors, etc.	10
Total	$520

A simplified circuit diagram is shown in Fig. 7. It is possible to use 60-cycle current for conductance measurements, thus eliminating the oscillator.

The cost of separate instruments to make these measurements is:

pH electrometer	$300
Manual polarograph	390
Conductance bridge	135
Total	$825

If no one with a knowledge of electronic instruments is available, any good radio serviceman can make the very simple additions to the meter. The added switch must be of high quality to prevent instability of the bridge.

The total cost of the complement of instruments for the small laboratory is between $2,600 and $3,600, depending on the scope desired. When good instrumentation can be provided for so little, there appears to be no sound reason for any laboratory to be without it.

Note: Mention of specific instruments by name in this paper has been made only to illustrate types and should not be construed as an endorsement of the products of any manufacturer.

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* A product of Klett Mfg. Co., New York.

† A product of Photovolt Corp., New York.

‡ Such as Beckman Model B. This instrument combines a Wheatstone bridge and a vacuum tube electrometer. It will be necessary to add provision for switching in an alternating-current power supply and possibly a meter capacitor to increase alternating-current sensitivity.

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Ion-Exchange Treatment of Water Supplies

By Joseph Thompson and Francis X. McGarvey

A paper presented on Oct. 30, 1952, at the Chesapeake Section Meeting, Washington, D.C., by Joseph Thompson, Sales Development Engr., and Francis X. McGarvey, Applications Engr., both of Resinous Products Div., Rohm & Haas Co., Philadelphia.

THE availability of a variety of new resins has, in the past several years, greatly expanded the application of ion exchange to the treatment of water supplies. These new products include cation-exchange resins of the weakly and strongly acidic types, anion-exchange resins of the weakly and strongly basic types, and highly porous modifications of the strong-acid cation exchangers and strong-base anion exchangers. Some of these products have been improved markedly for older, more conventional usages and others have suggested new techniques of real interest to those who are concerned with the treatment of water supplies. This paper will touch briefly on several of these applications.

Water Softening

Cation-exchange resins operating on the sodium cycle are being used widely instead of precipitation methods of water softening. Such resins have three principal advantages:

1. *Initial cost of equipment is low.* Not only do modern cation-exchange resins exhibit ten times the capacity of the older, low-exchange greensand materials, but the reaction rates of resins are such that the flow of water through a softener is limited only by the physical design of the unit. Flow rates as high as 10 gpm per square foot are now considered well within the limitations established by good engineering practice.

2. *A soft water of constant quality is produced regardless of variations in influent-water composition.* Raw-water hardness and total cation concentration have little effect on resin * exchange capacity. Moreover, the ratio of sodium ions to total cations influences exchange capacity only a little, as is shown by Fig. 1. On the other hand, the influence of water composition on the leakage of hardness through the ion-exchange resin is more apparent, as indicated in Fig. 2. In this study, a water with a 1,000-ppm total ionized solids concentration was used to illustrate the variable more adequately.

These data are of particular interest to water plant operators in the coastal areas, where the seepage from the ocean into wells or the backup of sea water into the river during periods of drought is encountered. In several installations, regeneration is carried out in the normal downflow manner, but raw water is passed through the resin upflow. This countercurrent opera-

* The resin employed as illustration in Fig. 1–4 is Amberlite IR–120, a product of Rohm & Haas Co., Philadelphia. This is a high-capacity, nuclear sulfonic acid type of cation-exchange resin.

tion has been instrumental in reducing leakage of hardness almost to zero.

3. *The cost of treatment by ion exchange may be lower.* Depending on the composition of the water, the cost of salt used for regeneration of the resin may be considerably lower than the cost of lime plus soda ash for precipitation treatment. For example, based on a regeneration efficiency of 0.25 lb of salt per kilograin hardness removed and a salt cost of 0.75 cents per pound, the cost of removal of 1 lb of hardness would be only 1.3 cents.

Treatment costs may be reduced still further by regeneration of the cation exchanger with sea water. Figure 3 shows the exchange capacities obtained when a resin is regenerated with various volumes of sea water. The information plotted in Fig. 4 permits the prediction of the effect of regenerant composition on the exchange capacity of a high-capacity cation-exchange resin. These data have been found particularly valuable in assessing the worth of brine wells for resin regeneration purposes.

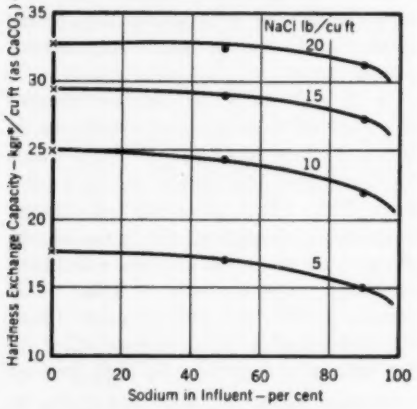

Fig. 1. Effect of Influent-Water Composition on Resin Exchange Capacity

Influent total solids—850 ppm (as $CaCO_3$); flow rate—2.5 gpm per cubic foot; endpoint leakage—1 per cent; 10 per cent brine regenerant.

* Kilograins.

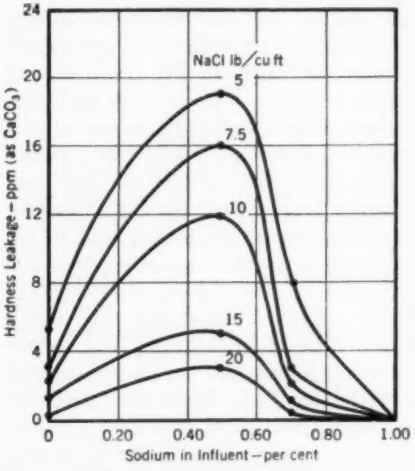

Fig. 2. Effect of Influent-Water Composition on Hardness Leakage

Influent total solids—1,000 ppm (as $CaCO_3$); the same resin was used as for Fig. 1.

New Applications

The mere substitution of a strongly basic anion-exchange resin for the cation-exchange resin normally used in a water-softening unit points to a really simplified method for the removal of such objectionable constituents as fluorides, excessive alkalinity, and sulfides from water supplies. Strongly basic anion exchangers in the free-base form behave as solid caustic with only hydroxyl ions in solution and will adsorb negatively charged ions from acid, neutral salts, and even mildly alkaline solutions. On the other hand, when regen-

erated with salt—that is, when used in the chloride form—these strong-base resins will exchange chlorides for fluorides, sulfides, bicarbonates, and carbonates. Although the equilibrium conditions for the adsorption of these anions are not entirely favorable because of the greater affinity of chlorides for the resin, the exchange is, nevertheless, sufficiently complete, and

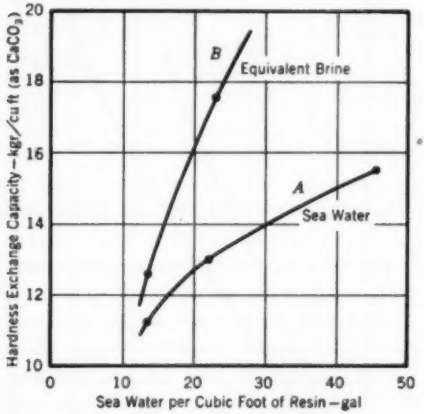

Fig. 3. Exchange Capacity With Sea Water Regeneration

Curve A *shows exchange capacities when various volumes of sea water (0.264 lb NaCl per gallon, Ca: Ca + Na ratio of 0.21) are used for regeneration. Curve* B *shows the equivalent standard brine regeneration level. The same resin was used as for Fig. 1.*

the use of salt as a neutral, inexpensive regenerant is so attractive that this new approach has generated widespread interest, particularly in smaller plants.

Fluoride Removal

Naturally occurring fluorides in excessive concentrations in raw-water supplies have always presented a problem. For example, it has been reported that the presence of more than 2 ppm fluoride (as F) in drinking water may cause mottling of teeth. Also, the fluoridation of municipal water supplies to combat tooth decay seems to

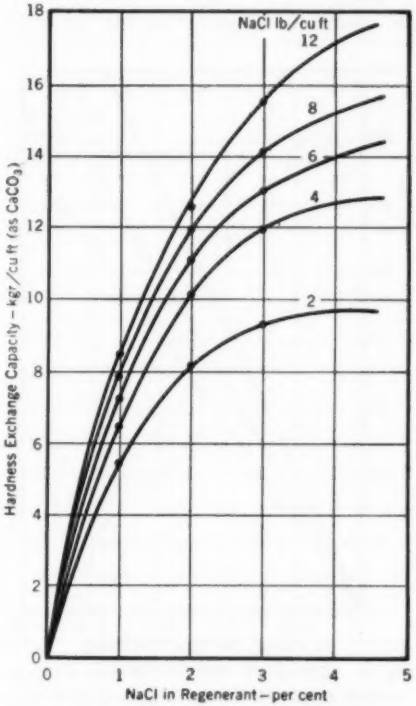

Fig. 4. Effect of Regenerant Composition on Exchange Capacity

These curves are applicable to the use of sea water for regeneration (based on a Ca: Ca + Na ratio of 0.21). The same resin was used as for Fig. 1.

have presented a problem to some food and beverage processors, apparently as a result of fluoride concentration during the process steps. In such instances, the use of a strongly basic anion-exchange resin in the chloride

form will serve to remove the fluorides effectively.

Figure 5 illustrates generally the effect of influent water composition on the fluoride exchange capacity of a porous modification of a strong-base anion-exchange resin.* The effectiveness of the treatment depends on the concentration of fluorides and the ratio of fluorides to total anions in the raw-water supply. Countercurrent operation is normally recommended. Although the resin exchange capacities shown are low, the usual fluoride influent concentration is also small, and adequate quantities of water can be treated. For example, preliminary laboratory work for a food-packing plant installation established the actual exchange capacity of another highly porous anion-exchange resin,† as a basis for treatment unit design. With a fluoride concentration of 4 ppm expressed as calcium carbonate ‡ and a fluoride–total anion ratio of 0.0417, the resin treated approximately 1,000 gal of water per cubic foot; the resin was regenerated with 2.5 lb of salt per cubic foot, using a minimum bed depth of 5 ft. Assuming the

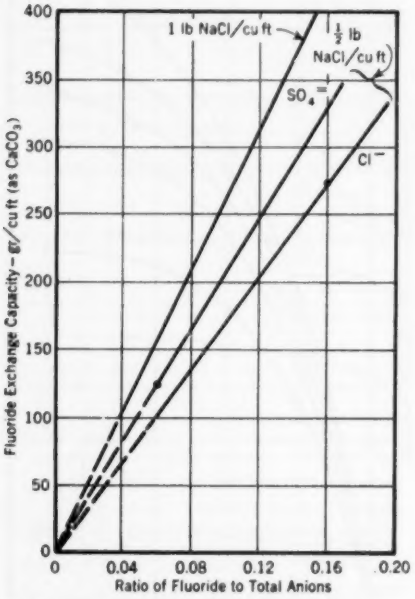

Fig. 5. Effect of Influent-Water Composition on Fluoride Exchange Capacity

A porous modification of a strong-base anion-exchange resin was used, with countercurrent regeneration.

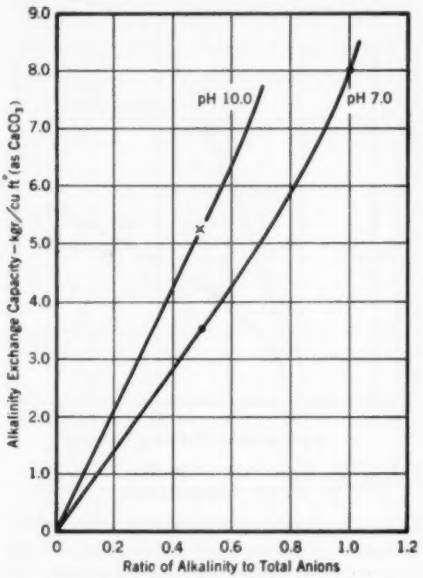

Fig. 6. Effect of pH on Alkalinity Exchange Capacity

The regeneration level was 4 lb of NaCl per cubic foot. Countercurrent regeneration was employed.

* Amberlite XE–75, a Rohm & Haas product, was used.

† Amberlite XE–98.

‡ Obtained by dividing ppm fluoride by the equivalent weight of fluoride and multiplying by the equivalent weight of calcium carbonate.

cost of salt to be 0.75 cents per pound, the cost of regenerant per 1,000 gal of water treated was 1.9 cents.

Alkalinity Reduction

Excessive concentrations of alkalinity in water supplies are usually objectionable for such applications as boiler feed, the production of carbonated beverages, and evaporative coolers. The dealkalization of water supplies by the use of the chloride form of a strongly basic anion-exchange resin has gained immediate acceptance throughout industry for the following reasons: [1] no fear of acid introduction to the treated water supply; [2] no handling of acids necessary; [3] acid-resistant equipment not required; [4] degasification equipment not needed; [5] no power costs required for pumping, because line pressure is not broken; [6] low regenerant cost; and [7] essentially constant treated-water alkalinity maintained regardless of fluctuations in raw-water supply.

Figure 6 shows the alkalinity exchange capacity of a strongly basic, amine type of anion-exchange resin * as a function of alkalinity to total anion ratio. It will be noted that the capacity increases with an increase in the alkalinity content or pH of the influent solution. Capacity improvement with increase in influent pH is to be expected because the divalent carbonate–chloride system is much more favorable than the monovalent bicarbonate–chloride.

Other investigators have found a similar capacity improvement when a small amount of caustic is added to the salt regenerant. Moreover, studies show a decrease in alkalinity leakage and removal of carbon dioxide with an increase in pH to approximately 9.5.

By combining, unmixed, an anion-exchange resin in the chloride form with a cation-exchange resin in the sodium form, some waters may be dealkalized and softened in a single column. Thus, in one operation, chloride ion is exchanged for alkalinity and sulfates,

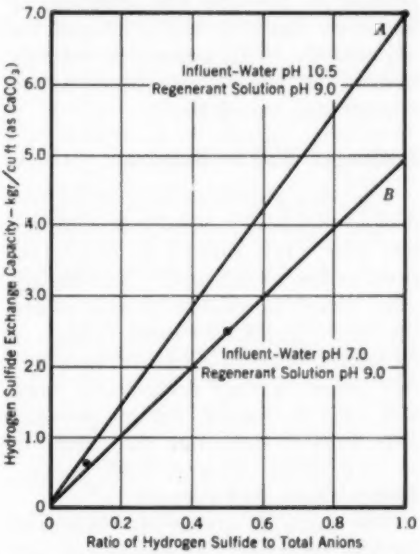

Fig. 7. Effect of pH on Hydrogen Sulfide Exchange Capacity

For both curves, the regenerant consisted of 5 lb NaCl and 1 lb $NaHCO_3$ per cubic foot.

and sodium ion is exchanged for calcium and magnesium. Both resins are regenerated with brine. Precipitation of hardness within the unit is avoided by drawing off the first portion of the waste regenerant at the junction of the two resin components. The remaining regenerant, relatively free of sulfates and carbonates, is then used for the cation-exchange resin.

* Amberlite IRA-410 was used.

Further work is now in progress to determine the extent of silica reduction to be obtained when regeneration with a combination of salt and caustic is used. It is interesting to speculate on the future of this development in the treatment of feedwaters for low-to-medium-pressure boilers if this investigation should prove successful. It is possible to visualize the reduction of hardness, alkalinity, and silica and the adjustment of pH, perhaps in a single unit, using only salt and caustic as the regenerating chemicals.

Hydrogen Sulfide Removal

The very objectionable odor of hydrogen sulfide is noticeable in cold water, even when present in concentrations as low as 0.5 ppm. Sulfides are often found in ground waters, where the concentration may range as high as 70 ppm. Not only does hydrogen sulfide impart a very disagreeable taste and odor to waters, but its presence also tends to accelerate the corrosion of such metals as iron, steel, copper, copper alloys, and silver.

The methods commonly employed for the reduction or removal of sulfides from industrial waters are aeration and chlorination. Aeration alone will reduce the sulfide concentration to a range of 1–2 ppm, while chlorination will effect complete removal. In either of these systems, free sulfur will be formed and may have to be removed by filtration or by coagulation and filtration. The first cost of equipment and the operating complexities of these methods generally prevent their use in domestic systems as well as in some industrial systems.

The use of a strongly basic anion-exchange resin in the chloride form shows promise as a new approach to this problem. In fact, a number of household installations have been made, with gratifying results. Figure 7 shows the effect of hydrogen sulfide–total anion ratios on the exchange capacity of a strongly basic, amine type of anion-exchange resin.* It is apparent that pH has an appreciable influence on the results obtained. Moreover, for most supplies, the choice of regenerant depends on the pH of the water to be treated. If the water has a pH value of more than 8.0, salt alone may be used; below 8.0, a solution of 90 per cent salt and 10 per cent sodium bicarbonate is recommended, except when treating waters with a pH of less than 7.0, where best results can be obtained by using sodium bicarbonate only. Finally, countercurrent regeneration is necessary to assure the completeness of sulfide removal during the run.

* Amberlite IRA–410.

Discussion

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The true worth of an ion exchanger can be determined only after long-term testing in equipment properly designed for its application. The comments in this discussion are based on field experience and results rather than on laboratory work.

Water Softening

The author is certainly correct in his point that the development of new resins has greatly expanded the application of ion exchange in water treat-

ment, as well as in other fields. Municipal water softening by ion exchange is particularly attractive when the raw-water supply is clear and free from objectionable suspended or organic matter. Furthermore, if a considerable portion of the hardness is noncarbonate or permanent, the cost of treatment by ion exchange may very well be lower than for softening by lime and soda ash. A careful study of the conditions is necessary, however, because if the hardness to be removed is predominantly calcium bicarbonate, lime softening will be more economical. An additional consideration is the fact that lime softening can be combined with clarification in one unit, the solids-contact process basin. A comparative study of treatment methods should be made, including such factors as first cost, operating cost, and relative simplicity of operation. As some applications of ion exchange are still in the experimental stage, such comparisons may not always be possible, particularly with regard to actual operating costs.

It is important that complete evaluations of new applications be made to avoid misapplying an exchanger. For example, a certain ion-exchange resin was claimed by its manufacturer to have color removal properties. This information was seized upon by an engineering organization designing a plant for removal of color from a surface water supply. Further investigation disclosed that the resin was entirely unsuitable for such work, and the usual coagulation treatment was subsequently specified for removal of the color.

In Fig. 1, the author has indicated exchange capacities of 17.5–33 kgr per cubic foot with the quantity of salt for regeneration varying from 5 to 20 lb per cubic foot and the exchange capacity showing only a slight drop even when the sodium in the raw water approaches 100 per cent. These data are confirmed by laboratory experience, but for field use the exchange capacity is not rated as high or as low as the limits shown in the graph. The author does not state whether his curves are based entirely on laboratory results or include field data as well. Referring to Fig. 2, the writer feels that the hardness leakage may also be affected by flow rate and bed depth, particularly in "upflow" softening.

Although ion-exchange treatment generally is cheaper than lime-soda treatment, the comparative cost of lime-soda and salt is only one of the governing factors. Municipal supplies are not normally softened to zero hardness. The lime-soda method usually is set up to reduce the hardness to approximately 5 gr by the control of the chemicals fed, but all the water is treated. The ion-exchange method requires the treatment of only that portion of the water necessary to give a blended effluent of 5-gr hardness. In making cost comparisons, consideration should also be given to the fact that, with ion-exchange softening, the effluent pH must usually be raised for corrosion control, whereas, with the lime-soda method, the effluent pH is generally satisfactory.

Sea Water Regeneration

The data on sea water regeneration are very useful in assessing the value of a natural brine for regenerating purposes. A cost comparison between artificial-brine and sea water regeneration should include the filtering and pumping costs of the latter, as well as the additional first cost for the larger

units which the lower exchange capacity makes necessary.

The relatively dilute concentration of sodium chloride in the sea water, as compared with that in salt brine, provides a less thorough regeneration. Hence, the exchanger is more sensitive to the composition of the raw water. In assessing ion-exchange for treatment with sea water regeneration, it is therefore important to be able to evaluate the effect of the particular raw water involved.

New Applications

In applying ion exchangers to fluoride removal, the author recommends countercurrent flow. The writer wonders whether this recommendation is based on laboratory findings or on field usage with large equipment and also what the residual fluoride content is. Although the author does give the bed depth—5 ft—no mention is made of flow rate.

The dealkalization of water with salt regeneration only has certainly been of interest to industry, particularly in the low-pressure boiler field where return condensate is a factor. The author states, however, that "essentially constant treated-water alkalinity [is] maintained regardless of fluctuations in raw-water supply." It is the writer's understanding that the effluent alkalinity is a percentage of the raw-water alkalinity.

It might also be mentioned that there are several other processes available for the removal of hydrogen sulfide in addition to those noted by the author. Manganese zeolite or a suitable type of activated carbon can be used.

New developments in ion exchangers, it should be pointed out, will require time and field application before their value can properly be judged. An ion-exchange process is no better than the mechanical equipment in which it is employed.

Water Authorities in Pennsylvania

By Samuel C. Braucher, Charles N. Fisher, I. S. Sahli, and J. C. DeGroot

A panel discussion presented on June 19, 1952, at the Pennsylvania Section Meeting, Erie, Pa., by Samuel C. Braucher, Deputy Secretary, Pennsylvania Dept. of Internal Affairs, Harrisburg, Pa.; Charles N. Fisher, Partner, Singer, Deane & Scribner, Pittsburgh, Pa.; I. S. Sahli, Chairman of the Board, Beaver Falls Municipal Authority, Beaver Falls, Pa.; and J. C. DeGroot, Mgr., Northampton Borough Municipal Authority, Northampton, Pa.

History and Present Status—*Samuel C. Braucher*

MEN of today live in the age of the simple solution. The ills of the flesh are to be cured by whatever vitamin or drug is the fad of the moment. Economic woes are to be banished by simple nostrums. Age-old prejudices are to be ended with a law. Man is seduced by simplicity. The seduction comes in many forms. In the theater and in novels the characters must be all black or all white. The heroine is virtuous, the hero brave, the villain unrelieved in his villainy, for dream children must not walk as man himself walks, wrapped in both good and evil. Public figures must be demigods or scoundrels, paeanized or muckraked. The idea must be streamlined, too. Man clamors for popular science and popular economics, by which he means one idea at a time, and that made palatable by refining it to insipidity.

Accordingly, municipalities are seeking the simple solution by which they may, painlessly and without effort, relieve themselves of the financial incubus of chronic deficits in the public service. One currently favored "cure-all" for the financial ailments of municipalities is the establishment of an authority.

The Pennsylvania constitution limits municipal debt, except in Philadelphia, to 7 per cent of the assessed valuation of taxable property in the municipality. The constitutional debt limit has remained unchanged for more than 75 years. The assessments, on which this borrowing capacity is based, have generally remained stable throughout the last generation. Other factors would tend to prevent increases in assessed valuations in any particular municipality, unless there is a general countywide or statewide equalization of assessments. Meanwhile, there has been a decrease in the purchasing power and value of money and a concurrent increase in construction cost.

This problem is not confined to local governments. During the same period, the debt of the national government has increased prodigiously. The Pennsylvania constitution has been amended to increase the commonwealth's borrowing capacity for certain specified purposes (highways and soldiers' bonus). Be-

cause of inability to increase its borrowing power still further, the state has resorted to use of the authority device, establishing a general state authority, a state public school building authority, and a state highway and bridge authority.

Municipal Borrowing Law

The constitution of Pennsylvania and the Municipal Borrowing Law (Act of June 24, 1941, P.L. 159, as amended) contain certain provisions under which borrowing by political subdivisions, for certain revenue-producing facilities, in excess of the debt limits, is permitted, but circumstances are such that these special powers are seldom utilized. The constitution provides that bonds for the construction or acquisition of water works, subways, underground railways, or street railways are not to be considered against the debt limitations if, for a five-year period, revenues from the utility have been sufficient to pay interest and sinking fund charges, or if the obligations are secured by liens on the respective properties and impose no municipal liability. The use of such utility bonds is limited for two reasons: [1] so few types of utilities are included—for practical purposes, in the average municipality, only water works; [2] the rigid interpretation of the provisions restricts the use of such borrowing to acquisition or construction and excludes extension or improvement.

The Municipal Borrowing Law authorizes the issuance of nondebt revenue bonds for the construction, acquisition, extension, or alteration of any public works. Such bonds are not secured by taxes and, therefore, are not chargeable against the borrowing capacity of the municipality. They are payable solely from the rentals, tolls, or charges imposed for the use or services of the utility. At present, nondebt revenue bonds are not being issued in Pennsylvania because leading bond attorneys refuse to approve them. In 1939 (*Lighton* v. *Abington Twp.*, 336 Pa. 345) the Pennsylvania Supreme Court invalidated an issue of such bonds by one township because it involved the establishment of a trustee to operate the utility in the event of default. A test case is needed to establish the legality of such bonds where no trustee is provided.

Authorities Acts

The 1933 General Assembly of Pennsylvania passed an act (P.L. 114) permitting counties of the second class to form corporations to be known as authorities, for the purpose of acquiring, constructing, and operating certain public projects which would be self-liquidating through rates or fees charged to those benefited by the service furnished.

The Pennsylvania Municipality Authorities Act (Act of June 28, 1935, P.L. 463) extended the field of these authorities to include all municipalities either singly or jointly. Amendments to the act were adopted at the 1937, 1939, and 1943 sessions of the assembly.

The 1945 session repealed the 1935 act and its amendments and substituted, in its place, the "Municipal Authorities Act of 1945" (P.L. 382), which was amended in the 1947, 1949, and 1951 legislatures. The 1945 act contains a provision that any authorities created under the acts of 1933 or 1935 and still in existence not only enjoy the powers and rights of the former laws, but also all the powers and rights of the 1945 act.

The authority, which is financed by revenue bonds, supplies a means by

which funds can be raised to construct or acquire revenue-producing proprietary facilities without in any way affecting the borrowing power of the municipality desiring the service.

A Pennsylvania municipal authority is a special type of public corporation limited to a life of 50 years and to certain noncompetitive, revenue-producing enterprises that will be self-liquidating from revenue. Municipal authorities are permitted to borrow without limit, provided that the indebtedness, payable from the revenues of the project, is repaid, with the proper interest, within 40 years. Then the project is transferred from the authority to the municipality or municipalities which created the authority.

Under the act of 1937 (P.L. 739, as amended), water supply works were among the projects that might be undertaken by authorities and this has been clarified to mean "water works, water supply works, and water distribution systems." Under the act of 1945, as amended, water authorities have been operating water works or water systems either directly or on a lease-back provision.

Generally, under the act of 1945, as amended, authorities are given power "to acquire by purchase, lease, or otherwise, and to construct, improve, maintain, repair, and operate" water works, water supply works, and water distribution systems. The Act of Assembly specifically grants the power of eminent domain for the purpose of acquiring lands, water, and water rights. Owners of existing water systems, whether public or private, are authorized under the act to lease, lend, grant, or convey their system or systems to authorities upon terms mutually agreed upon, which is usually performed by using the lease-back provisions of the law as interpreted and approved by the Supreme Court of Pennsylvania. Section 11 of the act of 1945, as amended, specifically provides that an authority may not acquire by eminent domain any property owned or used by the Commonwealth of Pennsylvania, any political subdivision thereof, or any property of a public service corporation. The purpose of this provision in the law is to prevent an authority from acquiring an existing water system from an unwilling owner. It is likewise provided that an authority cannot construct or acquire and operate a duplicate or competitive water system.

Establishing an Authority

The local governing body of the municipality may create a municipal authority by passing an ordinance or a resolution setting forth its intention to establish an authority and setting forth its purpose in the articles of incorporation. After proper public notice, these articles must be filed with the secretary of the commonwealth and approved by him before the certificate of incorporation is issued. Generally speaking, a board of five members is appointed by the governing body of the municipality for the purpose of directing, managing, and operating the authority. These members serve for staggered terms, not exceeding five years, and must be citizens of the incorporating municipality. This board elects its own officers, manages and controls the authority, and floats all bond issues. Under Pennsylvania law the bond issue of an authority need not have the approval of the department of internal affairs, as is required of municipalities floating general-obligation bond issues. In legislative circles the question has arisen whether or not the commonwealth should require bonds, issued by

an authority, to be approved by some state governing agency. The argument against such a requirement is that, as there is no limit placed upon authority borrowing, the right to issue such bonds is not involved, nor is any tax levy to amortize the bond issue required, for the bonds are secured by revenue only.

Under Act 108 of 1921 (P.L. 193) the secretary of internal affairs has the power and authority to require water authorities to file annual reports with the department of internal affairs. In 1951—at the request of the various units of local government, banks and bonding houses, the Pennsylvania Municipal Authorities Assn., and the American Water Works Assn.—the form of annual report previously required of water utilities was completely revised. The form was simplified without eliminating any of the information needed by the department of internal affairs.

Active Authorities in Pennsylvania

As of June 1, 1952, the records in the office of the secretary of the commonwealth showed that 516 municipal authorities had been created and incorporated in Pennsylvania. There was no breakdown to show how many of these authorities were general or special in nature. According to the available data in the department of internal affairs, the following authorities were then active:

Water	105
School	79
Sewer	67
Airport	11
Parking	10
Building (redevelopment and housing)	22
Other	6
Total	300

The records in the division of public utilities, department of internal affairs, disclose that for the year 1951, 90 active water authorities in Pennsylvania reported. A statistical breakdown of 87 of the 90 active water authorities reporting follows:

Fixed assets	$134,254,104
Current assets	$3,428,095
Reserve fund	$17,283,880
Total indebtedness	$110,534,859
Total current liabilities	$1,672,710
Total depreciation expenses	$327,803
Interest	$2,294,346
Retirement of bonds	$453,366
Reserve fund deposits	$515,333
Total income deductions	$4,441,768
Surplus available	$2,211,289
Number of metered domestic customers	236,445
Water furnished metered domestic customers—*1,000-gal units*	11,751,120
Actual billings, metered domestic customers	$5,991,596
Number of metered industrial customers	1,980
Water furnished metered industrial customers—*1,000-gal units*	20,564,901
Actual billings, metered industrial customers	$2,620,423

Authority Bonds

The law provides that, unlike general obligation bonds, the obligations of municipal authorities are not a charge against the credit or the taxing power of the municipality, nor is the municipality liable for the payment of principal or interest on any such obligations. In addition, the commonwealth assumes no liability whatever. Authority bonds, furthermore, are not secured by the property of the authority, but only by the revenues from the project operated by the authority. It is impossible to sell the assets of an authority to satisfy its bondholders.

The governing board of every authority is empowered to secure the payment of such bonds or any part thereof by pledge or deed of trust of all or any of its revenues and receipts; to make such agreements with the purchasers or holders of such bonds, or with others in connection with such bonds, whether issued or to be issued, as the authority shall deem advisable; and in general to provide for the security for such bonds and the rights of the holders thereof (Act of May 2, 1945, P.L. 382, as amended). The authority operates the utility at all events, so that the power to take over and operate the utility in the event of default is of no significance in Pennsylvania.

Bondholders' Rights

The Municipality Authorities Act contains a number of provisions for the protection of the bondholders. If a default lasts for 30 days, the holders of 25 per cent in aggregate principal amount of the bonds may, by an instrument properly filed with the recorder of deeds, appoint a trustee empowered (Act of May 2, 1945, P.L. 382, as amended) to:

1. In specified legal manner, enforce all rights of the bondholders including the right to require the authority to collect rates, rentals, and other charges adequate to carry out any agreement as to or pledge of the revenues or receipts of the authority, and to require the authority to carry out any other agreements with or for the benefit of the bondholders, and to perform its duties under the act.

2. Bring suit upon the bonds.

3. By action or suit in equity require the authority to account as it were trustee of an express trust for the bondholders.

4. By action or suit in equity enjoin any acts or things which may be unlawful or in violation of the rights of the bondholders.

5. By written notice to the authority, declare all bonds due and payable, and then, if all defaults are made good, to annul the original declaration and its consequences, provided the consent of the proper number of bondholders is obtained.

Any trustee is entitled to the appointment of a receiver. The trustee may take possession of the facilities of the authority, or any part of its facilities from which the revenues are applicable to the payment of the defaulting bonds. He may operate and maintain the facilities taken over, collecting and receiving all revenues, and depositing the amounts collected in a separate account, to be applied in the manner directed by the court of common pleas. Under no circumstances, however, may the receiver sell, assign, mortgage, or otherwise dispose of any assets belonging to the authority.

These rights are guaranteed to bondholders in every case. In addition, the authority, in its resolution authorizing the issue of bonds, may include other provisions which are to be part of the contract of the bondholders. These provisons may specify:

1. A pledge of the full faith and credit of the authority or limitation to all or any of the revenues of the authority from any or all projects or properties.

2. The duties of the authority in the construction and maintenance of the project.

3. The terms and provisions of the bonds.

4. Limitations on the purposes to which bond proceeds or federal loans or grants may be used.

5. Rates to be charged by the authority.

6. Setting aside of reserves and sinking funds and the regulations and disposition thereof.

7. Limitations on the issuance of additional bonds.

8. The terms and provisions of any deed of trust or indenture securing the bonds, or under which the bonds may be issued.

9. Any other or additional agreements with the holders of the bonds.

Obviously, these provisions are scrutinized very carefully by the bond houses before approving any authority bond issue. Authorities, their properties, operations, and securities, are free from all taxes under present laws and administrative rulings, except that the bonds are subject to estate and inheritance taxes. They cannot pledge the credit or taxing power of the state or any municipality and there is no means by which the municipalities or their taxpayers can be held liable for the payment of interest and principal of the revenue bonds issued by authorities.

Marketing authority bonds was difficult many years ago but authorities have now captured the popular fancy. Their bonds have a ready market among both individual and institutional investors. Revenue bonds have been issued for approximately 35 different purposes. The Pennsylvania law permits authorities to engage in that many different activities, but few such powers have been exercised and most of the authorities are for water supply or sewage purposes.

Conclusion

The Chinese definition of "crisis" is "danger with opportunity." Many local governments face a crisis. Danger is inherent in steadily increasing expenditures because of inflationary trends and the demand for new and better services. All the signs seem to indicate that local governments will be called upon to develop blighted areas, provide additional recreational facilities, furnish better educational opportunities, improve and expand transportation systems and parking facilities, increase police and fire protection, construct or enlarge water and sewer services, and perform other new functions requiring a sizable outlay of money. Opportunity challenges the legislative and administrative official alike to meet fearlessly and solve constructively these pressing financial problems. Most of the problems resolve themselves into the question of how to meet increasing cost from limited revenue sources.

Changes in Authority Bond Indentures—*Charles N. Fisher*

Changes in municipal authority bond indentures, although primarily a field for lawyers, are also of the greatest interest and importance to engineers and bankers. The discussion which follows is a survey of the changes in authority indenture requirements since 1939 as the banker sees them.

Since the passage of the authorities act in 1935, hundreds of authority bodies have been created under the laws of the commonwealth, but, at last report, only approximately 50 per cent of these were active, operating entities. Many of the others are completely dormant and will never be revived, but some are in the process of becoming active—that is, they are consulting with their engineers or architects, their bankers, and their lawyers in accomplishing the hundreds of details necessary to become a going concern. With

the passing years, there have been great and much needed changes and improvements in the indentures securing the authority bonds.

The fashion in authorities has changed. In the years before the war, the municipalities resorted to the authority method of financing primarily for water and sewer systems, but now there are also school authorities, parking authorities, municipal recreation authorities, arena authorities, and housing authorities. According to the law, no authority that is not revenue producing can be granted a charter, and the types are specified. The author is sure that if it were not for this provision, there would be many hundreds of other kinds, such as street-paving authorities and police authorities, for the authorities law has been a tremendous boon to the municipality hard pressed to find funds under the general-obligation borrowing power for needed municipal improvements.

Fortunately for the future generations of water users, sewerage system customers, school district taxpayers, and parking lot customers, the improvement in the indentures securing the bonds has kept pace with the changing fashions in authority financing. Documents are now used which, although far from perfect, are an infinite improvement over those of fifteen years ago.

Authority Bond Market

There was a very limited market for the authority bond of 1939–42. Customer reluctance had to be overcome, and some authorities suffered under the restrictive provisions of those early indentures, but the powers of the Authorities Act of 1935, before it was amended in 1947 and 1949, were limited, and the complete lack of operational experience resulted in errors on the side of tightness and rigidity rather than possible laxity.

Today, the investment banker can approach an authority transaction in a much more tranquil condition of mind because:

1. A greatly expanded market for the security exists.
2. Better operational practices—grown up through experience—can be relied upon.
3. Engineering is more sound. Many fallacies of the past have been exploded and many experimental theories expounded before the war have been proved to be sound and scientific logic.
4. A stronger financial background exists. Certain formulas and practices have not borne the test of time and other, sounder ones have taken their place.

The tendency nowadays is to weigh these factors and add to them the ever-present factors of the credit of the community and the character risk, as exemplified by the type of individuals on the authority board and the kind of people in the community. If the addition comes out on the plus side, a liberal indenture with all the modern trimmings can be had, and if on the minus side, a tight, but not hampering, document is issued.

New Liberal Rules

New, more liberal, and more flexible rules are now available to the high-grade authority group in its indenture. The indenture is the instrument of trust whereby the rights of the bondholders and the authority itself are defined. In a typical indenture are outlined a description of the bonds themselves; their authentication and delivery—that is, what must be accomplished before the bondholders turn

over their money to the authority and the bonds become a negotiable instrument; the revenues and funds of the authority, their flow and expenditure, and their accumulation; the covenants on the employment of a consulting engineer during the life of the issue and the employment of certified public accountants; the preparation of budgets; the carrying of insurance; the refunding of the bonds; and many other clauses and covenants which the experience of years has shown to be essential.

Although the average indenture of today appears infinitely more complex to the layman than that of twelve to fifteen years ago, this apparent complexity is merely an attempt by the engineer, the attorneys, and the investment banker to forestall the problems that have proved difficult in the past. The indenture of fifteen years ago, although seemingly simple, was actually rigid because of the minimum of experience behind its creation. The drafters of those early indentures were relying mainly on their experience with corporate bond indentures, but the differences are many—for example, the average authority, being a public body, must keep its rates as close to an operating balance as possible, while at the same time accumulating those surpluses necessary for future eventualities. The corporate bond, on the other hand, is always followed in the capitalization of the company by either preferred or common stock, or both, with the resultant much greater margins of safety. A good corporate bond will have a coverage of 300 or 400 per cent of its principal and interest requirements, whereas a coverage of only 120 per cent is deemed to be sufficient for a high-grade authority credit.

Many liberalizing tendencies have been incorporated into the present-day indenture. A few of the more important examples are:

1. Redemption provisions have been liberalized. Formerly, many bonds were issued as noncallable, and few bonds had a call date earlier than 10 years, but now it is a rare issue that does not have all of its bonds callable within 5 to 8 years, and some sooner, by utilization of a regular sinking fund, or on compliance with special conditions.

2. The handling of the funds of the authority has been liberalized. There is much less red tape and fewer multiple accounts, and much more discretion is given to the engineer and to the authority members—for example:

a. A clause is included to permit making capital expenditures, in the first instance, from operating funds without certification of the consulting engineer, such operating funds to be later reimbursed, at regular intervals, after the proper certification from the engineer has been obtained.

b. Employees of the authority are paid out of only one fund, the operation fund, instead of two or more, and this operation fund is later reimbursed from the capital fund or the construction fund, whichever applies, after the engineer has so certified.

3. The issuance of additional bonds has been considerably liberalized. The modern aggressive water authority that wishes to expand is no longer hampered by lack of funds, if their expenditure can be justified under certain formulas set up and certified by the consulting engineer, and the capital can be raised by the banker after analysis of the engineering figures.

4. The expenditure of reserve balances has been liberalized. It used to

be mandatory that 50 per cent or even higher percentages of the surpluses available after operating expenses and the setup of bond reserves be required for the retirement of bonds, leaving little or no funds for capital extensions or improvements. There is a modern trend for the disposition of these surpluses to be determined by an annual conference between the authority and its consulting engineer. After the needs of the immediate future have been met and proper emergency reserves provided for, however, it should be mandatory for the remaining surplus to be used for reduction of debt.

5. The modern indenture attempts to permit recognition of possible changes in the earning ability of the system so that possible periods of strigency will not necessarily forbid use of funds for desired and necessary capital expenditures, extensions, and improvements. Likewise, periods of great surpluses can be utilized for heavy payments on debt to the advantage of future years.

6. The original law did not expressly permit refunding, and in many indentures of that era, there was no clause which permitted the freeing of the bonds from the shackles of the indenture by deposit with the trustee of the entire amount of money required to pay them off completely. The modern indenture now permits bonds to be paid off, either from available annual surpluses, by a complete refunding operation, or by deposit of the entire amount of the funds required by the borough, which might conceivably obtain the amount from general-obligation funds. This ability to pay off the bonds permits not only a more rapid reduction of interest charges through annual payments, but also allows advantage to be taken of low interest rates, either in the authority bond market or in the general-obligation bond market, for a complete payment of the issue.

7. A new clause which has not been seen very often, but which the author believes to be desirable, is the permitting of short-term borrowing—once more upon compliance with certain formula requirements—and the refunding of this short-term borrowing by the issuance of longer-term bonds at some future date.

8. Often the old-style indentures specifically laid down, for all time, the rules for line deposits and tap fees. It is now considered extremely foolish to specify anything other than that such rules and regulations must be to the satisfaction of both the authority and the consulting engineer; the future rules and regulations are left to their discretion. Many an authority has been seriously hampered by its inability to take advantage of the growth in its neighborhood through too stringent line deposit regulations.

9. The banker, with his emphasis on good housekeeping, has always required that budgets be drawn up at least annually with the help of the consulting engineer. It is now considered proper, however, to permit modification in this budget during the year, with the consent of the consulting engineer, and it is even considered a debatable question whether or not capital expenditure should be budgeted at all, because of the possibly unnecessary stricture this imposes upon the healthy expansion of the authority.

Other Indentures

Most of the new liberal tendencies given apply specifically to water authority indentures, although the generalities, of course, have a broad application. It should be noted, however,

that with the growth of the sewer authority, a new field of indentures has been opened. This new indenture has developed because of the difficulty in obtaining a strong enough credit risk through a straight sewer revenue bond and the resultant necessity for resorting to lease-backs to the borough, tie-ups with the water system, and the use of special assessments.

Conclusion

Even more today than ever, the formation of an authority is a matter of teamwork, the members of the team being the originating municipal body, the authority members themselves, the bond attorneys, the solicitor for the authority, the consulting engineer, and the banker or fiscal adviser. All of these members of the team must be consulted and must be considered in the creation of a proper, modern, flexible indenture, but inasmuch as the responsibility for the future lies in the hands of the consulting engineer to such a great extent, the engineer should study the draft of an indenture very carefully and help the banker make it the way the engineer wants it.

Management Problems—*I. S. Sahli*

The author has been actively interested in the growth and proper control of municipal authorities throughout Pennsylvania. The Beaver Falls Authority has a total invested capital of well over $5,000,000 with total annual revenues of approximately $600,000.

The authority method of operating certain public services brings to a community the benefits of a businesslike administration of a private enterprise in an atmosphere of public ownership. As a whole, authority operations are just as successful as their management, and, in turn, their management is just as good as the political subdivision which creates them, inasmuch as the board members are appointed by the governing bodies creating the authority. In the appointment of board members, there are two apparent safety valves:

1. The board appointments are usually made for terms of five years with an expiration and subsequent appointment coming each year. Consequently, political upsets do not result in immediate change of the personnel of an authority board, and the program of policy on authority operation is stabilized.

2. Probably the most important safety feature is the requirement that operation comply strictly with the bondholders' indentures or bondholders' covenant. Thus, for the most part, authorities in Pennsylvania are able to operate in an atmosphere relatively free from political pressures.

Board Appointments

In the field of appointments, as elsewhere, there is no utopia. Board members should be appointed in a nonpartisan manner, but unfortunately this does not always happen. The influence of the bondholders, good legal counsel, and local public opinion, however, is ever present and, in the author's authority, at least, this influence has greatly controlled the city council in making board appointments or reappointments. Of course, there have been some very bad exceptions to this rule, which have reflected unfavorably on authority management in some communities—for example, a city council once appointed a man to an authority board because he was a master plumber. They backed up this appointment by

stating that as a plumber he would "come in handy" around the place. In another community, a member was appointed because his business connections enabled him to buy certain materials wholesale, and still a third because he needed the money—a director's fee of $25.00 a month. Most certainly, these men were not in a position to contribute the judgment necessary to administer the affairs of an authority, with a responsibility to both the bondholder and the community.

Good Management

There is no substitute for good management, which should be the prime responsibility of a board. The board should first place all the responsibility for operation in the hands of a good manager, properly defining the policies for him, and should then check regularly and carefully to see if the policies are carried out. The board should not attempt to execute policy. Interference from board members in management details only confuses a good manager and leads the way to a generally inefficient operation. Rarely do members of the author's board set foot on authority property between regular meetings, and when a member does, it is generally for a necessary or constructive purpose. Of course, personnel and management difficulties will from time to time require the attention of the board. Before placing blame on the manager or any of his subordinates, the board members should ask themselves these questions: Who hired this man? Who directed him? Who decided his salary? Has the board taken into consideration changing times, inflation, pensions, and competitive working conditions? Did the board consider these problems at the regular meetings? Sometimes it is not necessary to go out of the boardroom to find a solution for a so-called problem.

Authority Board Functions

The proper functions of an authority board include defining policy, giving the manager necessary authority to carry it out, and consulting with specialists—lawyers, engineers, bond experts, and the like—when problems involving policy decisions arise.

The author feels that the authority board should:

1. Act as "watchdog" over the bond indenture.
2. Take pride in its financial statement.
3. Take pride in the physical plant—its appearance and beauty.
4. Protect the credit of the authority (experience indicates that as the community expands, new bond issues are required and refunding of the old is often good business).
5. Respect the relationship with the trustees of the bondholders.
6. Attempt to assure continuity of management.
7. Consider fair and feasible pension plans.
8. Select legal and engineering counsel that is competent and interested.
9. Adopt a plan—perhaps a 5-year plan—in keeping with the growth of the community.
10. Consider its obligation to the entire community, rather than the political subdivision forming the authority.
11. Be willing to take risks in making extensions to keep pace with contemplated growth.

12. Be cognizant of its public relations, particularly if serving more than one community.

13. Report annually or regularly, in an organized manner, to the city council.

14. Be very careful in making statements on extension of authorities into other categories.

15. By precept and example, prove that water and other types of authorities are looking to the best interest of all the citizens.

The board should not:

1. Circumvent management on labor problems, procurement of materials, commitments, or extensions or, in fact, on any subject pertaining to operation.

2. Unduly solicit the city fathers to intervene in disputes with management.

3. Criticize without being fully informed.

4. Discuss labor or other problems with employees.

5. Encourage waste and spendthrift policies by exploiting expense accounts.

Operating Problems—*J. C. DeGroot*

Generally, routine operating problems under authority management are not different from those encountered under private ownership, holding company management, or direct municipal control. Usually, the operation of an authority project is delegated to a competent, professionally trained manager appointed by and responsible to the board. The board primarily acts as a policy-making group, and delegates complete control of personnel and other managerial functions to the manager.

Under such circumstances, a manager has entrusted to him tremendous responsibilities in carrying on the various phases of operation of the individual project in order to furnish efficiently the best type of service to the customers. These responsibilities include: [1] assurance that all provisions of the bond or trust indenture are complied with, in order to protect the bondholders fully; [2] effective maintenance of a well-knit, efficiently operating organization, including sponsorship of the best possible employer-employee relationships by paying adequate compensation commensurate with ability to produce, and by promoting and expanding welfare and security for all employees; [3] carrying on a project with the lowest possible operating ratio in order to assure progress; [4] handling all expansion problems requiring extension of facilities on a solid business basis; and [5] maintenance of cordial public relations with the consuming public.

If an alert manager can measure up to these requirements, and if the governing board fully recognizes its responsibilities and obligations to the bondholders, employees, and customers alike, a manager's life will run smoothly.

Extension Problems

This is an era of continual development and expansion, occasioned by a constant increase in population, an increase in expansion of industrial facilities, and an exodus of people from congested areas, all of which present problems in furnishing service to potential customers whose dwellings or factories are located or are to be located at points beyond existing facilities.

Requests for extension to meet service demands necessitate, in the author's authority, the extension of water mains ranging from 100 ft to 2,000 ft, and

costing from $400 to $8,000. Each individual request must be thoroughly analyzed and approached from a common-sense, business viewpoint. An estimate of cost must be prepared after a field survey has been made to determine the amount of investment needed and the anticipated revenue to be derived, both immediate and potential. These factors then determine whether a satisfactory net return will be derived. If the return will be satisfactory, the authority will make the installation at its own expense. If the net return is insufficient to warrant investment by the authority, several plans are offered to the customer. The customer can either contribute the difference between what the authority can expend and the total estimated cost, or the customer or customers can agree to a contract guaranteeing the necessary amount of revenue to provide the desired net return.

The Northampton Borough Municipal Authority requires that a main extension give a net return of 4.5 per cent. The annual revenue per domestic customer on the system is $22.00. With an operating ratio of 40 per cent, in order to arrive at a 4.5 per cent net return, the gross return must equal 7.5 per cent. In other words, using this formula, $270.00 per customer can be expended on a water main extension.

Therefore, in an extension of 1,000 ft of 6-in. main costing $4,000 to serve eight immediate and two potential customers, the authority would expend $2,700 and require a cash contribution of $1,300 as an aid to construction. When and if additional customers over the original ten contract for service and are placed in service, the authority refunds $270.00 per unit, on a proportional basis, to the original group that made the contribution, the total refunds not to exceed the original amount of deposit.

On the alternate plan, the potential customers could execute guaranteed-revenue contracts to provide a 7.5 per cent gross return on the investment. Such a guarantee would amount to $30.00 per annum each, with the proviso that each additional customer receiving service on this extension would automatically reduce the original guaranteed annual revenue by the amount of additional revenue received.

The author feels that this policy is liberal. Policies on main extension differ greatly among the different authorities in Pennsylvania.

Various Authority Policies

The Beaver Falls Municipal Authority reports that it will install 100 ft of 2-in. main for each new customer without cost to the new customer, but the customer must pay the cost of the extension beyond 100 ft. If other people are served by an extension of 2-in. line, a credit of 100 ft for each new customer will be given to the person paying for the extension when service is begun. In extending 4- or 6-in. mains which furnish fire protection as well as water supply, the Beaver Falls Authority will install 50 ft of main without charge for each new customer. The cost of an extension beyond 50 ft is divided equally between the customer and fire protection, so that the customer is directly charged with 50 per cent of the expense of the main beyond the 50-ft extension.

The Authority of the Borough of Charleroi requires each new customer to make a construction deposit equal to the cost of the extension. A refund for each customer served by the extension is made when a service line is connected and consumption begun.

The refund is computed at seven times the estimated annual consumption charge for each customer. No part of the deposit remaining after ten years from the completion of the extension will be refunded.

The Chester Municipal Authority will pay one-half of the cost of an extension.

The Clearfield Borough Authority negotiates with each person requiring an extension. The policy of installing 50 ft of main for each new customer is usually applied.

The Elizabeth Township Authority requires construction deposits equal to the entire cost of the extension. Deposits are returned to the persons making them as new customers are added to the extension. An amount equal to 3.5 times the estimated annual revenue contributed by each new customer is refunded. No part of the deposit remaining after a ten-year period is refunded. Because of the limit imposed on the authority by its indenture agreement, however, no refunds have been made recently.

The Gettysburg Municipal Authority requires a deposit equal to the entire cost of the extension. The entire deposit is returned, however, when the service connections are made to all the properties along the extension. Refunds are made for a twelve-year period from the date of the construction of the extension.

The Greenville Municipal Authority requires construction deposits equal to the cost of the extension. These are returned on the basis of 3.5 times the estimated annual revenue of each new customer served by the extension. The refund is made when new customers are connected and consumption started. No part of the deposit is returned after ten years.

The Hazleton City Authority also requires a construction deposit equal to the estimated cost of the line. A refund is made for each new customer added to the extension within five years of its completion. The refund is computed by multiplying the estimated annual revenue of each new customer by 2.5.

The Lansdale Municipal Authority will invest $100 on 6-in. mains for each new customer. If the extension costs more than $100 the customer must pay the balance. As other customers are added, $100 is refunded for each new customer. No refunds are made after eight years.

The Latrobe Municipal Authority requires construction deposits to cover the costs of extensions. A refund computed at nine times the estimated annual revenue contributed by each new customer connecting to the extension within five years of its completion is made.

The Lehighton Water Authority follows a policy identical with Latrobe's, except that the refund is computed by multiplying the estimated annual revenue of each new customer by 2.5. No part of the deposit remaining after five years from the construction of the extension is refunded.

The Lewistown Water Authority refunds the required construction deposits for extensions. A refund of $100 for each abutting property is made to the person making the deposit.

The New Kensington Municipal Authority refunds the construction deposit required for water extensions by returning an amount equal to seven times the estimated annual revenue of each new customer. No refunds are made for new customers added five years after the completion of the extension.

The North Versailles Township Authority will install up to 100 ft of main for each new customer when conditions affecting construction are "standard." If the required extension is longer or if rock is encountered, the person desiring the extension must pay the extra cost.

The Oakmont Municipal Authority will make extensions only if the person desiring service deposits the estimated cost with the authority. A refund of $75 is made for each customer connected to the extension and $150 for each fire hydrant. No part of the deposit remaining after ten years is refunded.

The Shenandoah Borough Authority requires construction deposits for each extension to its lines. A refund computed by multiplying the estimated annual revenue of each new customer by 2.5 is made when new customers are connected to the extension. No portion of the deposit remaining five years after the completion of the extension is refunded.

The State College Borough Authority will make extensions to its lines without an additional charge if the total cost of the extension does not exceed $100. If the cost of the extension is greater than $100, the authority offers two options to the person requiring the extension. One of these options provides that the person may either construct the extension using materials and specifications of the authority, or pay all costs over $100 if the authority builds the extension. The extension becomes the property of the authority upon completion, and the authority maintains the line. The person requiring an extension is then obligated to pay his regular water consumption charge or minimum water bill. If other customers are added to the extension paid for by any person, the State College Authority will connect their properties only if the new customers assume the proportional cost of the extension by making a payment to the original customer.

If a customer requiring an extension costing over $100 from the State College Borough Authority does not wish to construct or pay for the extension, the authority has an optional method of financing. This consists of the payment by the person of an annual "carrying charge" computed at 6 per cent of the cost of the line. The carrying charge is paid with the regular quarterly consumption charge, and, in addition, the customer must pay at least the minimum charge for water consumption. The carrying charge does not reduce the principal upon which it is computed. If other customers are added to an extension, the carrying charge is divided among them. If a further extension is added to an extension on which a carrying charge is being paid, the new extension will be treated separately if its inclusion would increase the charges already being paid. The minimum water consumption charges plus the carrying charges are calculated to give the State College Authority a return of 12 per cent on its investment in the water distribution system.

The West View Authority will invest $125 in an extension for each new customer. If the costs exceed $125 for each customer, the balance must be paid by the person desiring the extension.

The Wilkinsburg-Penn Joint Water Authority requires that construction deposits equal to the cost of the extension be made by all persons requiring extensions. The deposits are refunded to the persons making them. For each domestic customer added to the extension, $50 is returned and $1 for each

lineal foot of the extension is refunded if fire protection is contracted for by a municipality. Refunds are made for a period of 20 years.

The Williamsport Municipal Water Authority also requires construction deposits. The authority will make refunds computed at 6.66 times the estimated annual revenue for each new customer when he is connected to the extension. No portion of the deposit remaining with the authority after 12 years is refundable.

Municipal Leases

The water works in another group of municipalities in Pennsylvania, although owned by water authorities, are leased to the municipality for operation. The extension financing method for some of these follows:

Allentown makes special assessments apportioned by frontage for all water main extensions.

Bethlehem charges for extensions of mains over limits of 50 ft per customer in outlying areas.

Chambersburg makes special assessments apportioned by frontage against all properties served by the extension. The special assessments are then rebated by issuing credit to be used in paying water consumption bills. The rights to water assessment rebates may be assigned to other persons if property is sold.

Lebanon makes special assessments for outside customers only.

Quakertown main extension costs are paid by property owners through front-foot special assessments. For a period of five years the water bills are discounted 50 per cent, or until the credit equals the amount of the special assessment.

Water Service Installations

The author has ascertained that a number of authorities make a charge for water service installations. For a ¾-in. tap, New Kensington Authority makes a charge of $35.00; Muhlenberg Authority $25.00 plus paving costs; Latrobe Authority $35.00; and Hazleton $37.50 plus paving costs. At the Northampton Borough Municipal Authority, the authority installs the service connection to the curb, charging the customer for the paving costs. Without benefit of specific information, the author assumes that other authorities install and maintain service connections from the main to the curb.

Authorities Act

The general purpose and intent of the Authorities Act was to benefit the people of the commonwealth by giving them the best type of service at the lowest possible cost. Since the use of authority revenues are restricted to operating expenses, debt service, plant expansion, or rate reductions, it follows that the revenues available for extensions are very much limited after operating expenses and debt service requirements are met. The importance of analyzing each extension request on a common-sense, solid business basis should be reemphasized, for it is absolutely essential that the service charges approximate the costs of providing the service.

Public Relations

The importance of maintaining cordial relations with the consuming public should also be stressed. This problem can be minimized if the operating organization gives the manager full cooperation. If the meter reader, who

makes more contacts than anyone else, is courteous and answers all questions asked in a polite manner, customers will think he works for a good organization.

If the girl at the telephone in the office answers all questions in the proper manner, and can handle complaints in a diplomatic way, she can be a real assistant in helping public relations. If the girl at the counter is patient, explains at length the reason for abnormal bills, and can courteously answer any questions asked by the customer, this type of service will surely help improve public relations. If the foreman carries on his work efficiently, notifies customers of a shutdown for repairs, if possible, and is scrupulous in doing his work, the customers will think well of him and his organization.

Therefore, it seems to the author that public relations problems, as well as all of the other problems confronting a manager day in and day out, can be met and overcome if the operating organization and the governing board of the authority are steadfast in their desire to furnish the best type of service at the lowest possible cost to the consuming public. If this goal is followed through practically, the purpose of the act which provided for the formation of authorities will be fulfilled, and the successful progress of an authority project will be assured.

Cancellation of Specification for CA-50 Paint

By action of the AWWA Board of Directors on Jan. 19, 1953, approval of cold-applied coal-tar paint CA–50 has been rescinded and Sec. 5.4.5 and 7.3 deleted from the "Tentative Recommended Practice for Painting and Repainting Elevated Steel Water Storage Tanks, Standpipes, and Reservoirs—AWWA D102–52." It has been found that this cold-applied coal-tar paint, unless thoroughly and slowly dried, is likely to impart an unpleasant taste to water.

Selection of Pumping Equipment

By Thomas M. Niles

A paper presented on Oct. 30, 1952, at the Chesapeake Section Meeting, Washington, D.C., by Thomas M. Niles, Partner, Greeley & Hansen, Chicago.

THE selection of pumping equipment is a cooperative undertaking in which the best efforts of the pump designer and manufacturer must be brought together with the requirements of those who purchase and use the equipment. Broadly speaking, the purchaser determines and specifies the operating requirements of the installation, and the pump manufacturer designs, builds, and furnishes equipment that will perform the required service. Seldom, if ever, does the purchaser or his engineer attempt to design the equipment.

It is difficult to decide how far the purchaser should go in determining the requirements and at what point the manufacturer should take over. One extreme would be for the purchaser to have the manufacturer design and construct the entire pumping station, complete with building, equipment, and piping, to meet specified requirements for deliveries and heads. This would give the maximum latitude to the pump designer and manufacturer, and, with suitable general stipulations on materials and methods of construction and suitable provisions and guarantees of operating and maintenance costs and efficiencies, might well result in the least cost to the owner. Usually, however, such factors as space utilization, desired operation and maintenance programs, and integration with other facilities make this procedure impractical. The purchaser can best be assured that all of his requirements will be met properly by determining for himself what numbers, capacities, and types of pumping units should be used and how they are to be arranged and installed, and retaining the control of and responsibility for the pumping station design.

This paper makes no attempt to cover the entire field of pump installation or design. It is intended merely to outline and describe procedures that may be followed in arriving at sound conclusions regarding the equipment needed and the degree to which its characteristics and details should be made subject to the requirements of the specifications.

Few people can afford custom-made automobiles. Most are content with standard products which meet nearly all their needs and desires. Similarly, for the smaller pump installations, the dictates of sound economics point to utilization, wherever possible, of standard lines of equipment already developed and in manufacture. Only in the very large installations should it be expected that the pump design be tailored to fit the job.

The examples which follow generally involve works of comparatively large magnitude, where all of the con-

siderations covered are of importance. Many of the procedures are, however, applicable to smaller projects as well. Also, the examples are intended to cover primarily the investigations and determinations needed in connection with the pumping of water by electric power into a distribution system.

There is no such thing as a "typical" pumping station or a "typical" set of conditions. It is undoubtedly true that in no situation will all of the procedures and considerations apply without modification or adjustment to meet the requirements of the particular problem. Most of the procedures described, however, have been used with some degree of success in actual practice, and all of the problems discussed have been encountered in the design of pumping stations and the preparation of specifications under which the equipment is purchased.

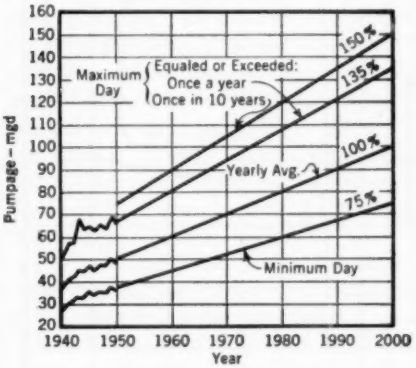

Fig. 1. Estimated Future Pumpage

By the year 2000, pumpage requirements are double those of 1950.

Quantity Studies

Basic to the selection of pumping equipment is the estimation of the quantities of water that must be pumped during the design period and the determination of the rates of delivery to be provided by the installation. Forecasts of future requirements take into account past records or estimates of pumpage and such considerations as population growth, commercial and industrial developments, and new uses for water.

Figure 1 illustrates in a manner convenient for reference certain results of the water quantity forecasts. The diagram shows, for a number of years in the future, the expected average yearly pumpage, the pumpage on the minimum day, and two lines for pumpage on the maximum day of the year, one of which is likely to be reached with some regularity and the other only at rare intervals, perhaps once in 10 years. On this diagram, estimated future pumpage requirements are shown up to the year 2000, by which time the requirements are indicated to be double those of 1950. Although it may be advisable to install equipment initially to be adequate for a considerably shorter period, perhaps 20 years or so, many pumping stations in operation today were built 50 or more years ago, and it is not unreasonable to consider such a period in the design of the station structures and piping.

The variations in daily and hourly pumpage may be estimated by an analysis of past records, conveniently plotted on probability paper to arrive at a curve of variations as shown in Fig. 2. In this example, the curve represents variations in daily pumpages expressed as percentages of the average rate of pumpage for the year. This curve is in agreement with the quantity forecasts shown in Fig. 1. Curves of this type may be used in estimating the per-

centages of time or number of hours or days during which pumpages at various rates will be required.

Future variations may differ from those of the past, and adjustments based on estimated future changes in the magnitude and timing of peak demands may be in order. Where high seasonal loads are expected to increase, the maximum pumpages may become progressively higher percentages of the yearly average rates.

Figure 3, showing hourly variations in pumpage on a maximum day, is typical of hourly variation curves that may be plotted from the records. The rate for each hour is shown as a percentage of the average for the 24-hour period. Figure 3 is a somewhat simplified presentation of data obtained from records at Washington, D.C., where the curves for the individual service areas are considerably different. In studying the requirements of a single system, it is desirable to plot curves of hourly variations for a number of the highest demand days of record, in order to arrive at a composite or "judgment" curve considered proper for design use.

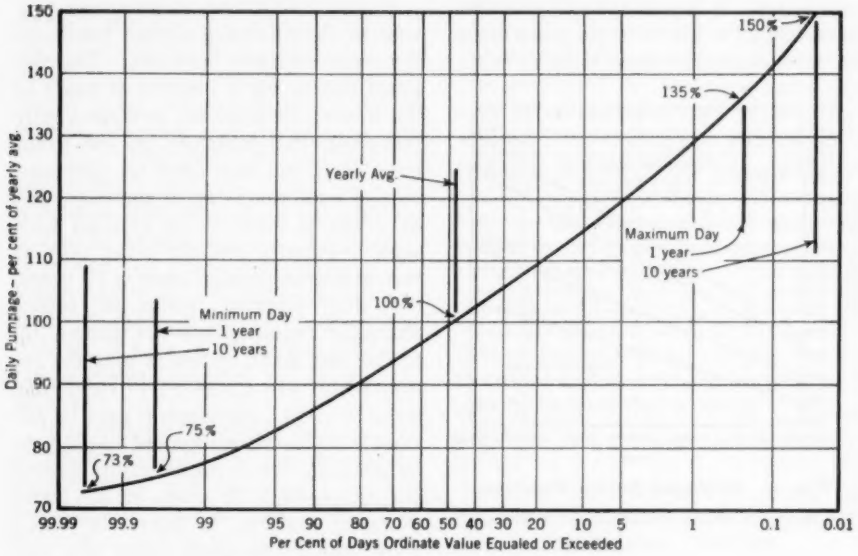

Fig. 2. Variations in Daily Pumpage Rate

The curve shows the percentage of days a given pumpage rate (expressed in terms of per cent of annual daily average) will be equaled or exceeded. Maximum and minimum daily rates are the same as in Fig. 1.

Studies of hourly variations are necessary in connection with nearly all pumping problems involving distribution systems, whether direct pumping with no distribution storage or pumping to a system with liberal or limited storage is involved. Even with storage more than sufficient to take care of

hourly variations on a maximum day, so that theoretically the supply to the system could be constant at the maximum-day rate, the variations in system hydraulics during emptying and filling the storage tank or reservoir may have a marked effect on the pumping heads.

Head Computations

Computations of the heads against which the pumps will operate are equal in importance to quantity studies and may well require the greatest effort, judgment, and ingenuity of the entire pump selection procedure. Figure 4 shows schematically a simplified version of a distribution system with direct pumping (no distribution storage), a maximum-day demand of 100 mgd, a maximum hourly rate of 130 mgd, and a minimum hourly rate of 55 mgd. These rates correspond to the quantities and percentage variations shown in Fig. 1–3 for a maximum day likely to be reached in 1967–74, assumed to be the limit of the design period.

As a first step, a simplified representation of the actual or proposed distribution system is worked out, such that the resulting study network has hydraulic characteristics similar to the complete system. The quantities of water leaving the system at or near the various intersection points are then estimated, as indicated on the plan view of Fig. 4 by the figures adjacent to the arrows. In this figure, the horizontal arrows below the plan indicate the estimated quantities flowing from left to right through the various sections.

Hydraulic computations are made for the direction and quantity of flow and for friction loss in each pipe of the simplified system for each set of conditions to be studied. These studies, usually made by the method of successive approximations, are quite laborious in a large system although routine in procedure. In simple systems and in portions of systems, further simplifications based on equivalent pipes, combined with intelligent approximations and judicious use of trial figures, frequently give sufficiently accurate results. When a large number of system studies are to be made, much time can be saved by the use of electrical-resistance hydraulic analyzers, several types of which are available.

The profile view of Fig. 4 represents the ground surface and buildings along the axis of the system. Required pressures are assumed to have been determined from consideration of the needs and types of development in the various areas. In an actual study, several such profiles or sections might be prepared. In this example, the controlling point is indicated to be a hydraulic gradient about 110 ft above the ground surface near the center of the city.

The computed hydraulic gradients for the maximum hour, the minimum hour, and the average rate on a maximum day of the design period are represented, respectively, by the three curves, *A*, *B*, and *C*, passing through the control point (assuming an exact fit of pump characteristics to these particular quantity and head requirements). At the pumping station, the elevation of the hydraulic gradient is indicated to be about 170 for the static condition (Curve *D*), 180 for the minimum hour, 200 for the average rate and 230 for the maximum hour. With direct pumping and without speed variations or throttling, the hydraulic gradients at the pumping station and throughout the system would at times

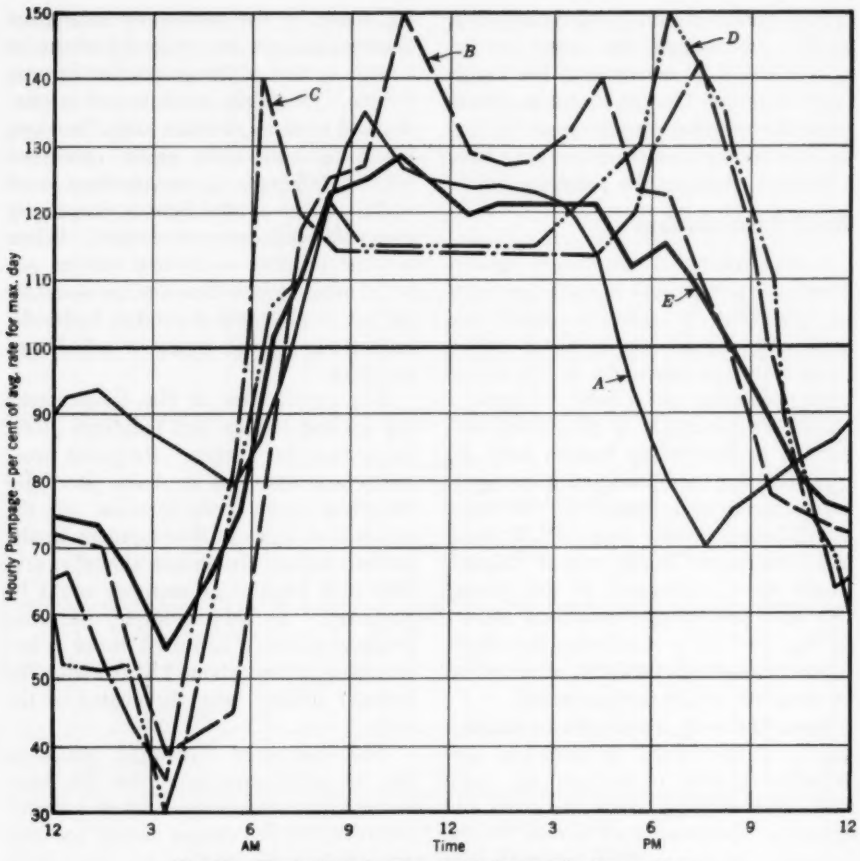

Fig. 3. Variations in Hourly Rate on Maximum Day

The curves show the hourly pumpage rates (in per cent of average rate) for various times during the maximum day. The data were obtained from Washington, D.C. Curve A *gives the hourly rates for the large central area; Curve* B, *for the intermediate area; curves* C *and* D, *for two outlying areas; and Curve* E, *for the entire city.*

be somewhat higher, as indicated by curves *E, F, G,* and *H.* Throttling at pump discharges would result in lower distribution pressures under such circumstances but would not affect the pumping heads.

Figure 5 shows the same system with the addition of an elevated storage tank or reservoir not far from the area of highest demand. The reservoir is assumed to be of sufficient size to permit constant pumping to the system at the average rate required for the 24-hour period—namely, 100 mgd—with flows from the reservoir to the system reaching a maximum rate of about 30

mgd during the maximum hour and with flows from the system to the reservoir reaching a maximum rate of about 45 mgd during the minimum hour, based on the hourly variations shown in

arithmetically by tabulation of the hourly flows.

The quantity takeoffs in Fig. 5 are the same as those in Fig. 4. The system quantities are the same to the

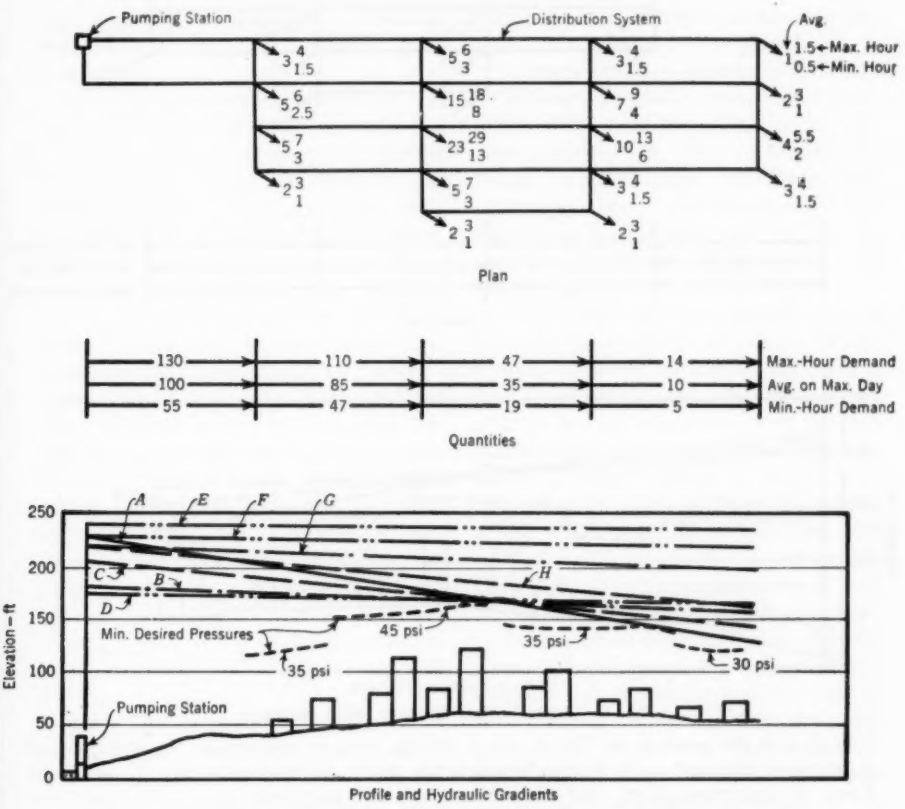

Fig. 4. Hydraulic Representation of Distribution System Without Storage

The various hydraulic gradients shown on the profile are: A, *maximum hour;* B, *minimum hour;* C, *average rate on maximum day;* D, *static condition;* E, F, G, *and* H, *higher gradients sometimes existing. The quantities shown in the plan are expressed in million gallons per day.*

Fig. 3. The usable volume in the reservoir, in this example, would have to be slightly over 10 mil gal, as determined graphically from a mass diagram or

right of the reservoir, but are substantially different between the pumping station and the reservoir. Hydraulic gradients through the system are not

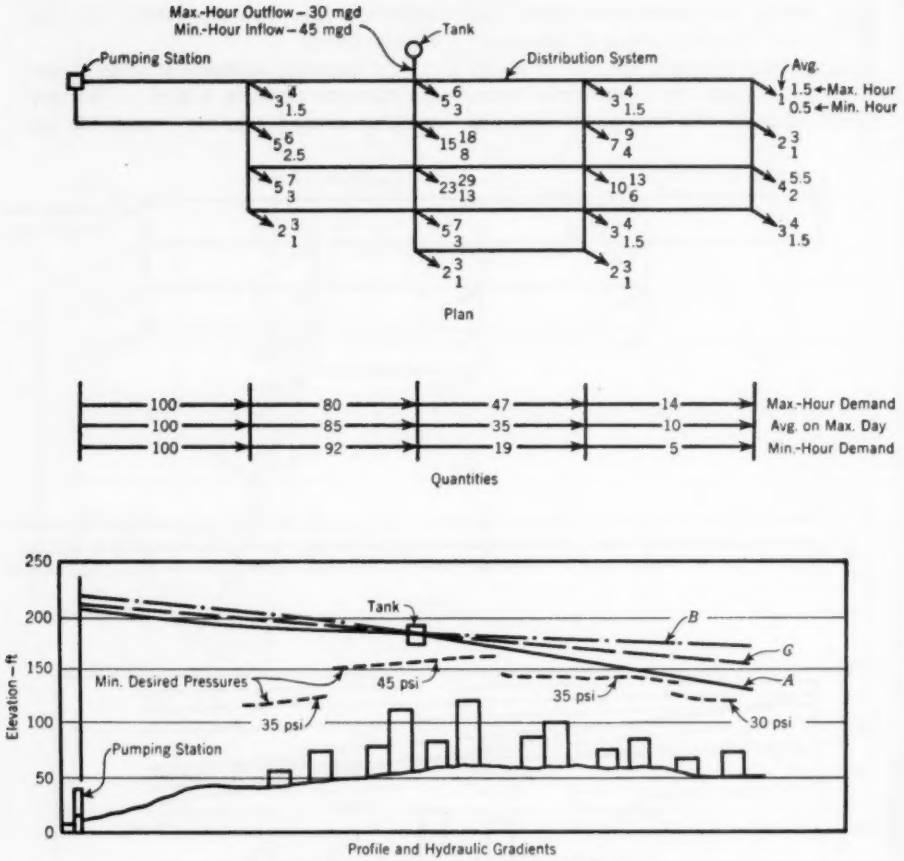

Fig. 5. Distribution System With Storage

The plan is the same as in Fig. 4, but a storage tank is assumed to permit constant pumping at 100 mgd. The hydraulic gradients shown on the profile are: A, *maximum hour;* B, *minimum hour; and* C, *average rate on maximum day. The quantities shown in the plan are expressed in million gallons per day.*

much different, except that the abnormally high pressures incident to constant-speed or unthrottled direct pumping do not occur. The hydraulic gradients vary only with the water surface elevation in the reservoir and with rates of flow. On the maximum day assumed, the gradients vary at the pumping station within a relatively narrow range, from approximately elevation 200 to approximately elevation 220. If the reservoir were located farther to the right on the system, away from the pumping station, the head variation would be greater.

Distribution system hydraulic computations are frequently complicated by the need for considering programs for

construction of extensions and relief mains.

The head at which a pump operates is commonly understood to be the difference between the energy gradients at the pump discharge and suction openings, obtained by adding the velocity heads to the respective hydraulic gradients.

For a given pumping condition, the head will be the difference between the hydraulic gradient leaving the station and the water surface elevation in the suction reservoir, plus the suction losses and the discharge piping losses within the station, with proper account being taken of suction and discharge velocity heads. The station losses are likely to occur principally in the individual pump suction and discharge connections and, accordingly, may not be much affected by the total station discharge. In a large installation, it may be worth while to make careful analyses of the station losses for different operating conditions. Sufficient accuracy is often obtained, however, by roughly estimating these losses under normal operating conditions and assuming them to be constant. Station losses frequently fall within a range of 3–5 ft.

With the completion of the head computations, station discharge curves may be prepared which show the approximate pumping heads under various conditions for the range of desired deliveries. Once prepared, these curves become the basis of the pump selection studies. Figure 6 represents station curves applicable to the direct-pumping system shown in Fig. 4, the curves corresponding to the minimum hydraulic gradients leaving the station which are required if adequate distribution system pressures are to be maintained. The upper and lower broken curves show the head requirements with lowest and highest expected suction water levels, with the solid line representing normal suction level operation. Additional curves would be needed if distribution system changes within the design period were contemplated.

Vertical lines are placed on the chart to indicate pumpage requirements under various conditions for the full design period. In this example, the yearly average rates, maximum and minimum days, and maximum and minimum hourly rates are shown for both the beginning and the end of the design period.

Head-discharge and efficiency curves for various numbers of pumps in operation, as shown in Fig. 6, are illustrative of what may be considered a first trial at pump selection, based on five pumps designed to operate at best efficiency at a head of 220 ft, two to be of 33-mgd and three of 50-mgd capacity at the rated head. It is seen that, with normal suction level, the maximum required rate of pumping can be met with one of the larger units out of service.

In the closed distribution system, the flow from the pumping station at any moment must equal the total demand of the system. Most of the time the pumps will operate at heads substantially higher than would be necessary to maintain adequate pressures in the system. With the operating procedure governed by the minimum satisfactory pressure at the control point, one or more pumps will continue in operation, on a rising demand, until the control point pressure reaches the allowable minimum, and at that time the operation will be changed to the next higher step in the combination. The new combination will then be pumping es-

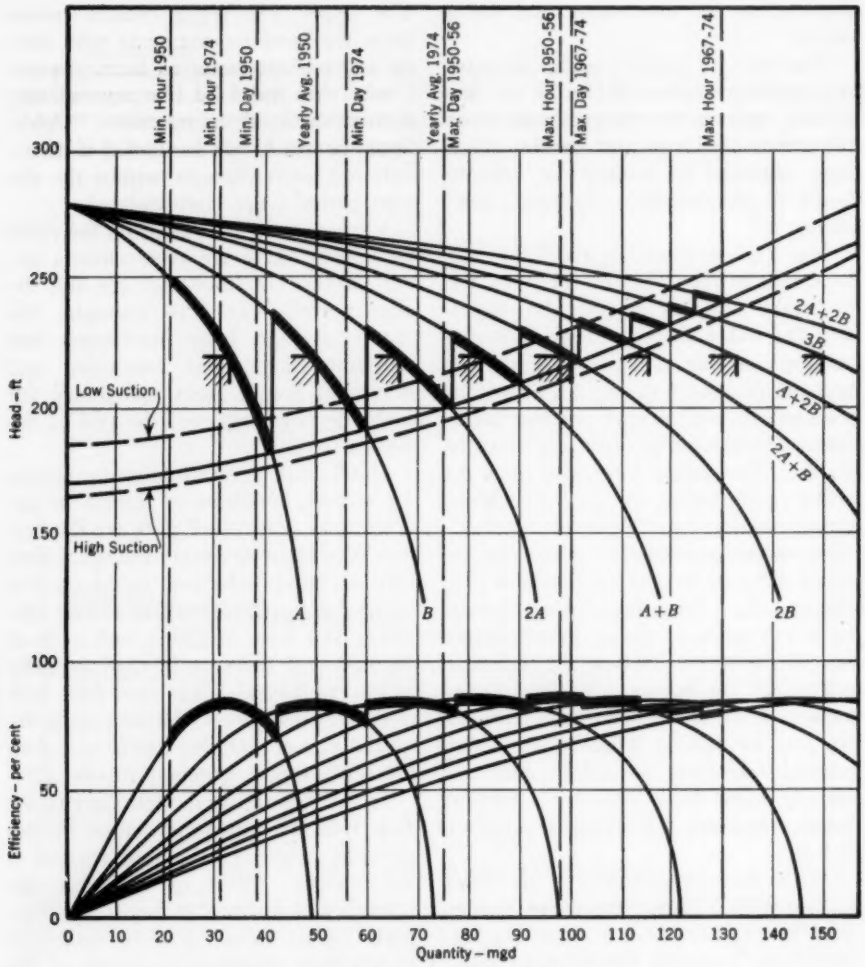

Fig. 6. Pump Selection Curves (No Storage)

The station discharge curves shown are applicable to the system in Fig. 4. The selection curves are based on combinations of five pumps of two types: A, *33-mgd capacity at a rated head of 220 ft (two units)*; *and* B, *50-mgd capacity at the same rated head (three units).*

sentially the same quantity of water, but at a higher head. The heavy portions of the head-discharge curves in Fig. 6 indicate the operating range for each combination of pumps. The heavy portions of the efficiency curves apply to the same ranges.

In the example shown, each step of operation requires starting one additional pump and stopping another.

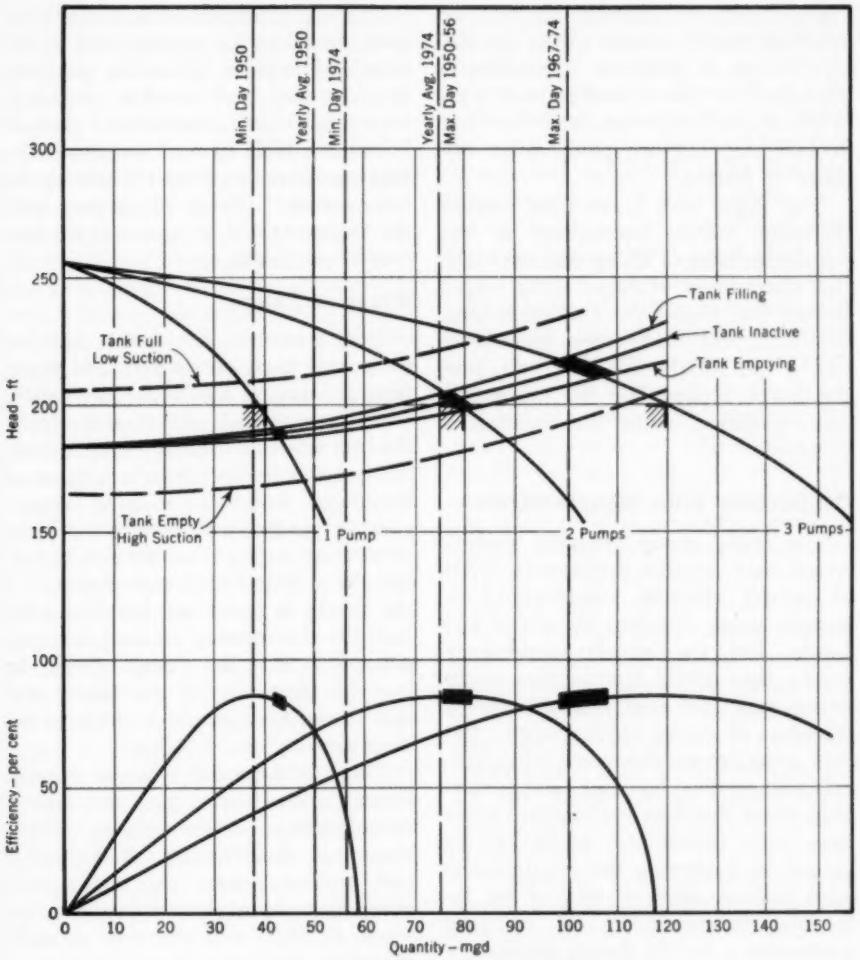

Fig. 7. Pump Selection Curves (With Storage)

These station discharge curves apply to the system with distribution storage shown in Fig. 5. Each pumping unit has a 40-mgd capacity at 200 ft head.

When this is done, only by careful manipulation of valves can high fluctuations in system pressure be avoided.

Figure 7 shows station discharge and pump selection curves for the system with distribution storage shown in Fig. 5. Here the maximum required rate of pumpage is 100 mgd instead of 130 mgd, and the requirements can be met by four units, each of 40-mgd capacity at 200 ft head, with one unit out of service. The distribution storage has taken over the job of pressure control, and the pump operation need be

changed only to maintain the tank or reservoir water surface within the desired range of elevation. Operation is always at the lowest head needed, is always at good efficiency, and does not require stopping one pump when another is started.

The upper and lower solid station discharge curves correspond to the maximum rates of filling and emptying the distribution storage. The upper broken line shows the maximum-head condition, with low-suction water level and a full distribution reservoir, and the lower broken line the minimum-head condition, when the situation is reversed.

Conferences With Manufacturers

The initial pump selection studies, which may involve preliminary trials of several alternate combinations of pumps, using different capacities and heads for the maximum-efficiency points, may utilize approximate pump curves estimated from available curves of pumps of similar requirements. Before going beyond the most preliminary selection studies, however, and preferably about the time the station curves have been determined, much can be gained by reviewing the requirements with perhaps three or four of the interested manufacturers of pumping equipment. As the design studies develop, further conferences should be arranged at which the more detailed requirements may be gone over, all to the end that the equipment specified will be practical and economical, that there will be unrestricted competition among those able to furnish proper equipment, and that the completed project will perform all desired services at the lowest cost.

The manufacturers should not, however, be asked for a great deal of detailed information before the pumpage requirements and station discharge curves have been determined. Also, it is not advisable to wait for local sales representatives to write the factory for information. Direct discussion with the engineers and designers at the factory is preferable.

Types of Pumps

Double-suction, horizontal centrifugal pumps have, over a period of years, become almost traditional for water works service and may continue to be the best selection for many installations. Recently there have been a number of important installations using single-suction, vertical-shaft pumps for high-service as well as low-service pumping, the principal advantages being: [1] the saving in space and building costs and [2] the meeting of the basic considerations that the pumps should be low for best suction conditions and that the motors should be high to reduce the danger of flooding.

There is some difference of opinion among water works men and among manufacturers on the relative advantages and disadvantages of horizontal and vertical pumps for high-service pumping. Apparently efficiencies are about as high with one type as with the other. Ease of access for inspection of parts and for replacements is important and should be considered, particularly in making a selection between different types of vertical units. For instance, if close-coupled volute vertical units provide for lifting the shaft and impeller clear of the casing after removal of the top head, dismantling and reassembly are relatively easy. On the other hand, if in order to remove

the impeller it is necessary to disconnect the suction piping and the bottom head and lower the impeller by means of jacks and false work, the procedure may be quite laborious.

If horizontal pumps are used, and if liberal drain capacity is not provided to carry away by gravity the water that might otherwise flood the motors in the event of a major break, the pumping units should be placed in compartments having watertight walls which extend above the maximum water level. Similarly, vertical units, if close coupled, should be placed in compartments unless there is no danger of flooding the motors. With vertical units and extension shafting, the motors can readily be placed at an elevation high enough to prevent flooding, thereby eliminating the need for compartments.

Examples of high-service stations where single-suction, vertical-shaft, close-coupled units have been selected, primarily on the basis of saving in space and resulting overall economy, are the new pumping facilities at Niagara Falls, N.Y., and the remodeled Bryant Street Pumping Station in the District of Columbia—both now nearing completion—and the proposed new Dalecarlia Pumping Station now under design for the Washington Aqueduct.

Selection of the type of impeller may usually be left to the pump designer, once the required operating characteristics have been determined. Centrifugal- or radial-flow impellers are characterized by comparatively flat head-discharge curves above the maximum-efficiency point and are more frequently used for high-head applications. The horsepower curves for these types are low at shutoff and rise as the delivery increases. Axial-flow propeller pumps, applicable to relatively low heads, have steep head-discharge curves with high shutoff heads, and the horsepower increases very substantially as the deliveries decrease. Mixed-flow impellers, having a combination of radial and axial components, cover the wide intermediate range and can be designed to meet a variety of requirements.

High-speed pumps and motors usually cost less than low-speed units, but relatively low speeds may result in quieter operation, less vibration, and longer life. The elevation of the pump with respect to the suction water level has an important bearing on the speeds that can be safely used without encountering cavitation difficulties. Although the manufacturers sometimes question the need for specifying the maximum rotating speeds that are to be used, a careful study of the relationship between the speed and the danger of cavitation may well be carried out as part of the pumping station design. Specific-speed calculations, including suction specific speed, deserve attention in any major project. In general, for single-suction pumps, suction specific speeds higher than 8,000 are approaching the danger point, while suction specific speeds of 6,000 or below are relatively safe.

When it is not inconsistent with the economy of the installation, the direction of rotation may be left up to the manufacturer. This permits the widest competition and may result in substantial savings in equipment cost.

Number and Capacity of Units

In specifying pump sizes, it is best to call for the capacity and head at the point of maximum efficiency, even though this may not be the point at which the pump normally will operate. In order that the pumps will de-

liver the required quantities throughout the operating range, minimum allowable capacities at the highest expected operating heads should also be specified. Frequently the minimum shutoff head is made a part of the specifications to avoid too flat a head-discharge curve. Some tolerance in capacities higher than the minimums specified should be permitted, perhaps up to 5 or even 10 per cent.

Where there is a considerable percentage range in heads over the range of expected demands, two-speed or variable-speed units may be advantageous, although the first cost will be higher than for single-speed units and more space will be needed for electrical equipment. For variable-speed units, efficiencies will be lower and heat losses greater.

The operation should be satisfactory, without cavitation, throughout the normal operating range. This is particularly important during low-head operation when the operation may be at points considerably to the right of the maximum-efficiency point.

For some installations, the best pump selection will include units of different sizes, particularly where there is little or no distribution storage and where the demands must be followed closely by the pump operating steps. Sometimes the pumps used at the lower-head conditions will not be operative at the higher-head conditions. If the percentage variation in head is not great, there is some advantage in rating all of the pumps at the same head and, insofar as practicable, using pumps of the same size. If relatively small intervals between the steps of the various pump combinations are needed, the provision of two small pumps, each two-thirds the capacity of the larger units, will permit operating steps of one-third the capacity of the larger units. This is the basis on which the pump curves shown in Fig. 6 were selected.

When storage is available on the distribution system, the required operation can often be met by pumps all of the same size and rating. This arrangement results in economy of purchase and, because of interchangeability of parts, economy of maintenance.

Every important installation should be capable of meeting the pumping requirements with at least one unit out of service. In some plants, two reserve units are provided. It is always possible that, when one unit has been taken out of service intentionally, for repair or maintenance work, an unexpected outage of another unit will occur.

Operating Procedures

The manner in which the pumps will be operated frequently has a bearing on the pump selection. For instance, if the pump is to be started against a closed discharge valve, the horsepower curve should be such that the motor will not be overloaded at the shutoff point.

Objectionable surge during normal operating procedures may be avoided by slow opening and closing of the pump discharge valve when a unit is put into service or taken out. When power or mechanical failure results in sudden stoppage of the pump, objectionable surge can be avoided only by surge suppressors or other relief devices or by slowly closing the discharge valve to permit relief of the surge wave back through the pump. During the latter procedure, some reverse flow through the pump may be expected until the valve is closed, together with reverse rotation. The speed of the re-

verse rotation, even with unrestricted supply of water to the pump, will probably not exceed approximately 120 per cent of the designed forward speed, and, if the pumping unit is designed to be structurally adequate and properly lubricated during reverse rotation at such speed, no harm will result. These requirements can readily be met by the pump manufacturers.

Because the cost of operating and maintenance labor, as well as of repairs and replacements, may be different for different types of pumps, this factor must be considered in deciding on the type and arrangement of the equipment. Ease of access for inspection of bearings, wearing rings and impellers, requiring a minimum of effort in routine maintenance, may well justify higher first cost.

Automatic operation of pumping stations may sometimes be advisable as an economy measure. If the installation is relatively complex, there is some danger that the saving in operating personnel will be more than offset by the cost of keeping the automatic controls in proper operation. Generally, if operators are on hand, as is nearly always true at a large station, or even at a small station built and operated as part of a water plant, manual operation has many advantages.

Partial automatic operation, applied, for instance, to the sequence of starting and stopping pumps and opening and closing discharge valves, is frequently desirable even in an attended station.

Arrangement, Piping, and Valves

Dependability of service is the most important objective in suction and discharge piping arrangements. Next in importance is the arrival at the proper balance between head losses and initial cost. Provision of somewhat liberal sizes for the main suction and discharge piping and headers is desirable, to permit future installation of larger pumps if necessary.

Within reasonable limits, it is permissible to specify the diameters of the suction and discharge openings, in order to avoid the necessity for difficult adjustments and changes in the adjacent piping and valves to fit the pumps purchased. For example, if a valve of the rotating-plug type is to be placed close to the pump on the discharge side, and if a 24-in. diameter is sufficient and proper, the diameter of the discharge nozzle should be so specified. Otherwise, the successful bidder on the pump contract may furnish an odd size, such as 26 in., or an unduly large size, perhaps 30 in., for the discharge nozzle. The cost of using a special or larger-size discharge valve may be substantial.

The station dimensions should be based on the use of pumps known to be obtainable from a number of manufacturers, and the specifications should require that any pumps offered be of such dimensions that they will fit the space available.

Foundation and anchorage requirements should be worked out at the time the general type of pumps and number and sizes of units are determined, and pertinent information on these items should be given the pump manufacturers before bids are received.

Suction valves are usually needed to permit work on the pumps. If suction piping is used, the valve should be placed far enough from the pump to avoid objectionable disturbance of the flow entering the pump. If the valve must be close to the pump, it should be

TABLE 1

*Sample Estimate of Power Requirements**

1	2	3	4	5	6	7	8	9	10	11	12	13
Time *hr/yr*	Avg. Rate *mgd*	Col. 1 × Col. 2	Q_a† *mgd*	Q_b‡ *mgd*	Col. 1 × Col. 5	$Q_b - Q_a$ *mgd*	Col. 6 − Col. 3	T_a§ *hr*	T_b‖ *hr*	$T_a \times kw_a$	$T_b \times kw_b$	Col. 11 + Col. 12
										1,000 kwhr/yr		
1955–59												
876	48	42,000	44	78	68,300	34	26,300	773	103	997	250	1,247
3,504	55	193,000	44	78	273,000	34	80,000	2,360	1,144	3,040	2,780	5,820
3,504	61	213,000	44	78	273,000	34	60,000	1,770	1,734	2,280	4,200	6,480
876	71	62,200	44	78	68,300	34	6,100	180	696	233	1,690	1,923
8,760								5,083	3,677	6,550	8,920	15,470
1960–64												
876	52	45,500	44	78	68,300	34	23,200	683	193	880	470	1,350
3,504	59	207,000	44	78	273,000	34	66,000	1,940	1,564	2,500	3,800	6,300
3,504	67	235,000	44	78	273,000	34	38,000	1,120	2,384	1,440	5,780	7,220
876	77	67,400	44	78	68,300	34	900	26	850	35	2,060	2,095
8,760								3,769	4,991	4,855	12,110	16,965
1965–69												
876	56	49,000	44	78	68,300	34	19,300	570	306	735	740	1,475
3,504	63	220,000	44	78	273,000	34	53,000	1,560	1,944	2,010	4,720	6,730
3,504	72	252,000	44	78	273,000	34	21,000	620	2,884	800	7,000	7,800
876	83	72,700	78	103	90,000	25	17,300	690	186	1,670	635	2,305
8,760								3,440	5,320	5,215	13,095	18,310
1970–74												
876	60	52,600	44	78	68,300	34	15,700	462	414	595	1,000	1,595
3,504	68	238,000	44	78	273,000	34	35,000	1,030	2,474	1,325	6,000	7,325
3,504	78	273,000	44	78	273,000	34	0	0	3,504	0	8,500	8,500
876	89	78,000	78	103	90,000	25	12,000	480	396	1,160	1,360	2,520
8,760								1,972	6,788	3,080	16,860	19,940

* Assuming 4 pumping units, each 40-mgd capacity at 200-ft head:

1 unit operating—44 mgd at 190 ft, 83 per cent efficiency, 1,730 hp = 1,290 kw
2 units operating—78 mgd at 202 ft, 85 per cent efficiency, 3,250 hp = 2,420 kw
3 units operating—103 mgd at 214 ft, 84 per cent efficiency, 4,590 hp = 3,420 kw

† Q_a—rate of pump delivery next lower than average.
‡ Q_b—rate of pump delivery next higher than average.
§ T_a—figure in Column 8 divided by figure in Column 7.
‖ T_b—figure in Column 1 minus figure in Column 9.

of a type that will cause little disturbance. Butterfly valves have been used successfully for such installations. If the pump suction takes water directly from a suction well, the shutoff provision may be in the form of a sluice gate or even stop logs used with a suitably compartmented well. If the pump is of a type that can be removed entirely for servicing, as is true of deep well turbine pumps or the pullout type of vertical propeller pumps, shutoff provisions may not be necessary.

In any event, the arrangement and hydraulic characteristics of the suction piping, conduits, or wells will affect the

operation of the pumps and, accordingly, should be reviewed with the interested manufacturers before the pump selection is made. Such data should also be shown on the drawings that accompany the pump purchase specifications.

Motors

Determination of the most advantageous types of motors and the voltage at which they will operate is an important part of the pump selection studies. In this matter, too, much can be gained by conferring with the manufacturers of the equipment. The local power utility should also be consulted. At large installations, the motors may be designed for operation at relatively high voltage.

For large motors in which heat losses would cause undesirably high room temperatures, water-cooling facilities may be provided as part of the motor, utilizing water from the discharge side of the pump which is wasted after passage through the cooling coils.

When synchronous motors are used with a group of pumps, direct-connected exciters may be installed on the individual motors, or excitation may be provided by separate equipment operating through an excitation bus. There are advantages and disadvantages in each arrangement. Individual motor excitation has been selected in a number of stations to avoid the danger of all the units going out at once because of failure of the excitation equipment.

Efficiencies

For all but the smallest installations, overall efficiencies should be about as high as possible, and every reasonable effort should be made to insure that initially high efficiencies will not fall off after a short operating period. Premium efficiency motors are frequently worth their additional cost and should be given full consideration.

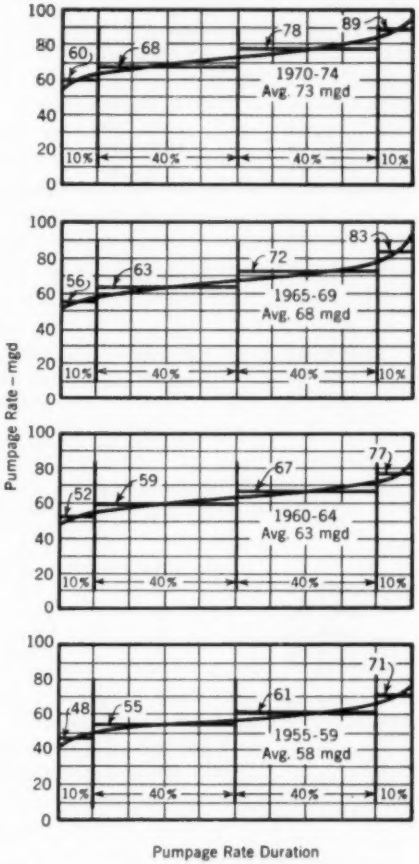

Fig. 8. Duration Curves for Pumpage Rates

These curves indicate the percentage of time a given pumpage rate will occur in each 5-year period from 1955 to 1974. The horizontal axis is divided into 10 per cent intervals. For each curve, average pumpage rates are shown for the high and low 10 per cent periods and for the two intermediate 40 per cent periods.

TABLE 2

Sample Estimate of Efficiency Value

Power Requirements (85% Max. Efficiency)

Period	Estd. Avg. Power Requirements *kwhr/yr*	Max. Demand			
		High Months		Low Months	
		No.	*kw*	No.	*kw*
1955–59	15,470,000	1	3,420	11	2,420
1960–64	16,965,000	3	3,420	9	2,420
1965–69	18,310,000	5	3,420	7	2,420
1970–74	19,940,000	7	3,420	5	2,420

Estd. Annual Power Cost (85% Max. Efficiency)

Period	Energy Cost ($0.007/kwhr) $/yr	Demand Charge ($1/month/kw)			Total Power Cost $/yr
		High Months $	Low Months $	Total $	
1955–59	108,000	3,500	26,500	30,000	138,000
1960–64	118,000	10,200	21,800	32,000	150,000
1965–69	128,000	17,100	16,900	34,000	162,000
1970–74	139,000	24,000	12,000	36,000	175,000

Estd. Increase in Power Costs for Lower Max. Efficiency

Period	No. of Years	Cost Increase			
		84% Max. Efficiency		83% Max. Efficiency	
		$/yr	5-yr Period $	$/yr	5-yr Period $
1955–59	5	1,640	8,200	3,320	16,600
1960–64	5	1,790	8,950	3,610	18,050
1965–69	5	1,930	9,650	3,900	19,500
1970–74	5	2,080	10,400	4,220	21,100
1955–74	20		37,200		75,250

Estd. value of 1 point of max. efficiency, averaged for entire group of pumping units, is approximately $37,000

Sample Acceptance Test Results

Pumping Unit	Max. Efficiency %
No. 1	84.9
No. 2	83.7
No. 3	84.8
No. 4	84.6
Avg. 1–4	84.5

Reduction in price of equipment:
$0.5 \times \$37{,}000 = \$18{,}500$

No uniformly satisfactory method of evaluation of efficiencies in connection with the purchase of pumping equipment has been worked out. Without question, high efficiencies are worth money to the purchaser and low efficiencies are costly.

To arrive at the value of efficiency for a group of pumping units, an analysis may be made of the probable number of hours of operation of various units in the group over a period of years; the probable cost of power at a given efficiency can then be estimated. Figure 8 shows one method of arriving at an approximation of the pump operating times. For each of four 5-year periods, a curve is plotted indicating the percentage of time a given pumpage rate will occur. Approximate average pumping rates are shown for the high and low 10 per cent periods and for the two intermediate 40 per cent periods. In this example, which is related to the quantities and variations shown in Fig. 1 and 2, the variations between the successive 5-year periods are quite regular. In a particular instance, unequal periods might be selected, to fit expected changes in the distribution system or other facilities, and the increases in pumpage would probably not be uniform.

Using the estimated average pumpages for the various percentages of time, as obtained from Fig. 8, computations may be made of the approximate number of hours per year during which different numbers of pumping units will operate, and the total use of energy per year estimated therefrom. An example of this computation is shown in Table 1.

Table 2 shows a way in which the power estimates may be used to arrive at a value for the efficiency. The power requirements in this example include estimates of the maximum demand in various periods and the estimated power cost, with energy and demand charges, all based on an assumed 85 per cent overall maximum efficiency.

Two computations of increased cost of power by 5-year periods are shown, one assuming an efficiency of 84 per cent and the other, an efficiency of 83 per cent. It thus appears that the estimated value of one point of maximum efficiency, for the entire group of pumping units, is approximately $37,000.

The table also shows the way in which this valuation may be applied to the results of accetance tests. If, for instance, the average overall efficiency for the group of pumps is 84.5 per cent and the base price of the equipment is related to 85 per cent, the reduction in price, computed to the nearest one-tenth point of average efficiency, would be $18,500.

Other Considerations

There are a number of miscellaneous items that should be considered in selecting and specifying pumping equipment. Among them are:

Vibration. It is desirable to place some measurable limit on the magnitude of vibration that will be acceptable.

Noise. Pumps are ordinarily specified to operate quietly, without excessive noise. This is indefinite and some method by which noise could be measured would be desirable. Some consideration should be given to finding a workable means of specifying and testing allowable decibel noise levels.

Bearings. The number, type, design, and method of lubrication of bearings should all receive attention and be covered by the specifications.

Wearing rings. Generally speaking, wearing ring clearances should be sufficient to permit operation without rubbing and to avoid rapid dropoff of efficiency after a short period of operation.

Seals and packing. The desires of those responsible for operation and maintenance should be given full consideration in the matter of design, accessibility, and materials used for packing and seals.

Assembling and dismantling. The arrangement, design, and assembly of parts should be such that necessary dismantling and reassembly for inspection and maintenance operations may be performed with a minimum of inconvenience.

Replacement parts. A reasonably adequate supply of replacement parts should be furnished with the pumping equipment, together with any special tools that are necessary or particularly useful in working on the equipment.

Testing

If shop testing facilities are adequate, acceptance tests can usually be better made at the manufacturer's plant than in the field after installation. The decision on the location of the acceptance tests should be made after conferences with the various interested manufacturers.

Insofar as practicable, the manufacturers prefer that test procedures recommended by the Hydraulic Institute be followed. If, however, the acceptance tests are to be made in the field, it is sometimes not possible to follow these procedures in all respects. In any event, it is desirable to describe in some detail in the specifications the exact way in which the equipment is to be tested for acceptance.

Conclusion

Proper pump selection must be based on:

1. Thorough analysis of the rates at which water is to be pumped.
2. Determination of heads throughout the range of operating conditions.
3. Information from manufacturers on the types, sizes, and characteristics of equipment that can be furnished.
4. Consideration of the desires and preferences of the operating personnel.
5. Determination of the best type of equipment for the job.
6. Determination of the proper number of units and their hydraulic characteristics.

In addition, to be sure that the equipment furnished will be satisfactory, such features of the design and manufacture of the units as speed, bearings, lubrication, ease of maintenance, and other details, together with the testing operations and procedures, should be investigated and specified.

Thorough and competent studies on the selection of pumping equipment will result in adequate installations that meet all operating requirements with the fewest difficulties and at the lowest cost.

UDC 621.774.1

ASA A21.6-1953
(AWWA C106-53)

American Standard Specifications

for

CAST IRON PIPE CENTRIFUGALLY CAST IN METAL MOLDS, FOR WATER OR OTHER LIQUIDS

PUBLISHED BY AMERICAN WATER WORKS ASSOCIATION, INC.

SPONSORS

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Table 6.1—Standard Dimensions of Bells, Sockets and Outside Diameters—and Weights of Bells—of Pipe Centrifugally Cast in Metal Molds.

Table 6.2—Standard Thicknesses, Diameters and Weights of Pipe Centrifugally Cast in Metal Molds.

Table 6.3—Standard Thicknesses and Weights of Pipe Centrifugally Cast in Metal Molds (Classes 50–350, laid without blocks, on flat-bottom trench, with tamped backfill, under 5 ft of cover).

Table 6.4—Standard Thicknesses of Pipe Centrifugally Cast in Metal Molds (for laying conditions A, B, C and D, pressures 50–350, and 3½, 5 and 8 ft of cover.

NOTE 1—Tables showing additional thicknesses required for greater depths of cover and other conditions of laying will be found in ASA A21.1.

NOTE 2—Users of these tables are cautioned to select fittings having proper socket dimensions and thicknesses suited to the pressures. Pipe specified in these tables have outside diameters which will chamber correctly with existing standards for pipe and fittings.

Users of this document should make reference to "American Recommended Practice Manual for the Computation of Strength and Thickness of Cast Iron Pipe" (ASA A21.1) for complete information concerning the conditions which various thicknesses of pipe are designed to meet. The foreword of the Manual also contains a statement regarding the history of the specifications and references to other related documents.

UDC 621.774.1

ASA A21.6-1953
(AWWA C106-53)

American Standard Specifications for

Cast Iron Pipe Centrifugally Cast in Metal Molds, for Water or Other Liquids

This specification covers cast iron pipe centrifugally cast in metal molds.

Sec. 6–1—Definitions

Purchaser. Wherever the word "purchaser" is used herein, it shall be understood to mean the actual purchaser of the pipe or his authorized agents acting within the scope of the duties entrusted to them.

Heat. A heat is a period during which a cupola or furnace is operated continuously.

Run. A run is a period of one or more shifts during which a shop is operated continuously.

Mixture of Iron. Mixture of iron is a combination of pig iron, scrap, coke and other raw materials charged to a cupola or furnace to give a desired composition of iron; or a combination of molten iron from one or more sources, made in a forehearth or ladle to give a desired composition of iron.

Source of Iron. A source of iron is a cupola, furnace or forehearth from which iron is delivered to a transfer or pouring ladle.

Forehearth. A forehearth is a refractory-lined receptacle for the temporary storage of molten iron from one or more cupolas or furnaces.

Sec. 6–2—Description of Pipe

The pipe shall be made with bell and spigot ends, plain ends or such other type of ends as may be agreed upon at the time of purchase. Pipe with bell-and-spigot ends shall conform to the dimensions and weights shown in the tables given in this document. Pipe with other types of ends shall comply with the dimensions agreed upon, but in all other respects shall fulfill the specifications hereinafter given. Pipe shall be straight and shall be true circles in section, with the inner and outer surfaces concentric. Pipe shall be cast at least 12 ft in nominal laying length. This type of pipe is commonly made at present (1952) in 12- and 18-ft lengths.

Sec. 6–3—Casting of Pipe

The pipe shall be centrifugally cast in metal molds, and after withdrawal from the molds pipe shall be heat-treated to meet the requirements of this specification.

Sec. 6–4—Quality of Iron

6–4.1. All pipe shall be made of cast iron of good quality, and of such

character and so adapted in chemical composition to the thickness of the pipe to be cast, that the iron in the pipe shall be strong, tough, resilient, of even grain and soft enough for satisfactory drilling and cutting, and it shall comply with the physical specifications given in Sec. 6–17 and 6–18. The metal shall be remelted in a cupola or other suitable furnace.

6–4.2. The iron in the pipe shall not contain more than 0.90 per cent of phosphorus nor more than 0.12 per cent of sulphur. Samples for chemical analyses shall be taken by drilling completely through from skin to skin either acceptance test specimens or specimens cast for this purpose, but not to exceed three specimens per heat of approximately eight hours. In case of dispute, analyses will be determined on samples taken from the pipe in question.

Sec. 6–5—Quality of Castings

The pipe shall be smooth, free from scales, lumps, blisters, sand holes, laps and defects of every nature which unfit them for the use for which they are intended. No plugging, filling, burning-in or welding will be allowed except as permitted by the purchaser.

Sec. 6–6—Foundry Records

A record of the results of the following tests shall be made and retained for at least one year. Upon request such record will be available to the purchaser at the foundry. If written transcripts of the results of any of these tests are desired this fact shall be noted in the order for pipe, naming the tests of which transcripts are desired. The methods of testing and the dimensions of all test specimens are given in the Appendix.

6–6.1. *Chemical analyses.* Chemical analyses of each iron mixture used directly in the pouring of pipe, obtained as in Sec. 6–4.2, shall be made for silicon, sulphur, manganese, phosphorus and total carbon during the first hour and at intervals not to exceed three hours throughout the heat. If pipe are poured directly from the cupola, chemical analyses shall be made of iron from the first and from the last ladle. If the mixture is changed one or more times during a heat in order to produce a different iron, the time of taking samples shall be varied in such a way as to obtain representative tests of the iron at least at the beginning and end of each period during which the iron is intended to be constant in quality.

6–6.2. *Pouring temperatures.* The pouring temperature of the iron shall be taken at the casting ladle for each size of pipe at least once each hour.

6–6.3. *Hardness tests.* See Sec. 6–17.2 and Appendix Sec. 6–A1—Talbot Strip Tests.

6–6.4. *Talbot strip tests.* See Sec. 6–17.1.

6–6.5. *Periodic ring, strip and full-length bursting tests.* See Sec. 6–17 and 6–18.

Sec. 6–7—Marking Pipe

Each pipe shall have the weight and class designation conspicuously painted on it. In addition, each bell-and-spigot pipe shall have distinctly cast or stamped on the face of the bell the manufacturer's mark and the year in which the pipe was cast. When specified by the purchaser, the manufacturer's mark, the year in which the pipe was cast and initials not exceeding four in number shall be distinctly cast on the face of the bell. The size of

letters and figures is to be as large as practicable. Pipe with ends other than bell and spigot are to be marked as agreed upon at the time of purchase.

Sec. 6–8—Inspection by Purchaser

6–8.1. *Power of purchaser to inspect.* The purchaser shall have free access at all times to all parts of any manufacturing plant which concern the manufacture of articles to be made for him. He may inspect the material, pattern work, molding, casting, heat-treating, coating and lining of the pipe. The forms, sizes, uniformity and conditions of all pipe herein referred to shall be subject to his inspection and approval, and he may reject, without subjection to hydrostatic test, any pipe which is not in conformity with the specifications or drawings. Any pipe rejected shall be so marked and any marks pertaining to the purchaser shall be chipped or erased from such pipe.

6–8.2. *Manufacturer to furnish men and materials.* The manufacturer shall provide tools, testing equipment, materials, labor and facilities necessary for the required testing, inspection and weighing of the pipe at the foundry.

6–8.3. *Report of purchaser's inspection.* The purchaser shall make written report daily to the foundry office of all pipe rejected with the causes for rejection.

Sec. 6–9—Inspection and Certification by Manufacturer

Should the purchaser have no inspector at the works, the manufacturer shall, if required by the purchaser, furnish a sworn statement that the inspection and all of the tests have been made and met as specified. If written transcripts of any of these test results are required, including chemical tests if desired, a request specifying the tests of which transcripts are desired shall accompany the order.

Sec. 6–10—Pipe to Be Delivered Sound

All the pipe shall be delivered in all respects sound and in conformity with these specifications. The inspection shall not relieve the manufacturer of any of his obligations in this respect, and any defective pipe which may have passed the purchaser at the works or elsewhere shall be at all times liable to rejection when discovered, until the final completion and adjustment of the contract; provided, however, that the manufacturer shall not be held liable for pipe found to be damaged after they have been accepted at the agreed point of delivery, unless there shall be unmistakable evidence that the casting was originally defective or damaged before acceptance. Care shall be taken in handling the pipe not to injure the coating or lining, and no pipe or other material of any kind shall be placed in the pipe during transportation or at any other time after they have received the coating or lining.

Sec. 6–11—Cut Pipe

Defective spigot ends on pipe may be cut off in a manner which will produce a square end. Not more than 10 per cent of the total number of pipe of each size of a given order may be shipped as cut pipe. Such cut pipe when cut from 12-ft lengths shall have a nominal laying length of not less than 11 ft; pipe originally of 16-ft or greater length shall not be cut more than 2 ft.

Sec. 6–12—Tolerances or Maximum Permitted Variations

6–12.1. *Pipe and socket diameters.* Outside diameters of pipe barrels and spigot ends, and inside diameters of sockets, shall be kept as nearly as practicable to the specified dimensions. The inside diameters of the sockets and the outside diameters of the spigot ends shall be tested with circular gages. Tolerances or maximum permitted variations from standard dimensions are listed below:

Nom. Pipe Diam. *in.*	Tolerances *in.*
3–12	±0.06
14–24	±0.08

6–12.2. *Thickness.* The minus tolerances from standard thickness of pipe and dimensions *a*, *b*, *c* and *d* of the bell are as follows:

Nom. Pipe Diam. *in.*	Minus Tolerance *in.*
3– 8	0.05
10–12	0.06
14–24	0.08

Note: In pipe barrel thickness, tolerances 0.02 in. greater than those listed above shall be permissible over areas not exceeding 8 in. in length in any direction.

6–12.3. *Weight.* The weight of no single pipe shall be less than the nominal tabulated weight by more than 5 per cent for pipe 12 in. or smaller in diameter, nor by more than 4 per cent for pipe larger than 12 in. in diameter. The total weight of any order of 25 tons or more shall not be more than 2 per cent under the total nominal weight. The total excess weight to be paid for on orders of 25 tons or more shall not exceed 2 per cent of the nominal weight and on orders of less than 25 tons shall not exceed 5 per cent of the nominal weight. An order is hereby defined as including all the pipe ordered under the terms of a specific contract or purchase order or a single order placed under the terms of a standing contract. Unless otherwise specified in the contract, a ton shall be 2,000 lb avoirdupois.

Sec. 6–13—Cleaning and Inspecting

All pipe shall have fins and other roughnesses chipped or ground off and shall be thoroughly cleaned, checked as to dimensions and also subjected to a careful inspection and a rolling test, before being coated or lined.

Sec. 6–14—Hydrostatic Test

Each pipe shall be subjected to a hydrostatic proof test. This test may be made either before or after a hot or cold bituminous dip or paint has been applied but shall be made before the cement mortar lining or any other special lining has been applied to pipe for which such lining is specified.

The pipe shall be under the test pressure for at least one-half minute. Any pipe showing defects by leaking, sweating or otherwise shall be rejected. The test pressures shall be in accordance with the table appearing on page 195.

Sec. 6–15—Weighing

Each length of pipe shall be weighed and the weight plainly marked on the outside or inside of the bell or spigot end. Pipe shall be weighed before the application of any lining or coating other than hot or cold bituminous dip or paint.

Table of Hydrostatic Test Pressures

Nom. Pipe Diam. *in.*	Nom. Barrel Thickness *in.*	Test Pressure *psi*
3–12	all thicknesses	500
14	0.57 and less	400
14	0.58 and over	500
16	0.60 and less	400
16	0.61 and over	500
18	0.65 and less	400
18	0.66 and over	500
20	0.70 and less	400
20	0.71 and over	500
24	0.75 and less	400
24	0.76 and over	500

Sec. 6–16—Linings and Exterior Coatings

Any particular lining or coating which is to be applied to the pipe shall be specified in the agreement made at the time of purchase. Separate specifications for cement-mortar lining (ASA A21.4, also known as AWWA C104) have been provided in connection with specifications for pipe.

No pipe for water works service shall be furnished without protective coating unless specifically ordered by the purchaser.

Sec. 6–17—Acceptance Tests for Physical Properties

The standard acceptance tests for the physical characteristics of the pipe shall be as follows:

Sec. 6–17.1—Talbot Strip Tests

Talbot strip tests shall be used to determine the acceptability of 3-in. to 24-in. pipe for modulus of rupture and secant modulus of elasticity.

17.1.1. *Sampling.* For sampling, every run shall be divided into periods of approximately three hours each, and at least one sample shall be taken during each three-hour period. The sample for the first period of the run shall be taken during the first hour or, if casting is direct from the cupola, from the first ladle. Samples shall be taken so that each size of pipe cast for two hours or longer during the run and each mixture or source of iron used for two hours or longer during the run shall be fairly represented.

17.1.2. *Method of testing.* The method of testing Talbot strips is given in Sec. 6–A1 of the Appendix.

17.1.3. *Acceptance values.* The acceptance values for tests on Talbot strips from 3-in. to 24-in. pipe shall be as follows:

Modulus of rupture: 40,000 psi minimum

Secant modulus of elasticity: 12,000,000 psi, maximum

If the modulus of elasticity exceeds 12,000,000, the modulus of rupture shall exceed 40,000 in at least the same proportion.

Sec. 6–17.2—Hardness Tests

On the outside of each pipe a hardness determination shall be made with a portable instrument. The Rockwell hardness number or its equivalent shall not exceed B–95, using a ball having a diameter of 1.59 mm ($\frac{1}{16}$ in.) and a weight of 100 kg (220.5 lb). Any harder pipe may be re-heat-treated to meet this requirement. For the purpose of the foundry records (Sec. 6–6.3), hardness tests shall be made also on Talbot strips as noted in the Appendix under "Talbot Strip Tests"—viz., a Rockwell hardness test at three well distributed points each on the outside of the pipe and on one machined face shall be made and recorded.

Sec. 6–18—Periodic Ring Tests and Full-Length Bursting Tests

The manufacturer shall periodically make such bursting tests and ring tests in conjunction with strip tests that he can certify the design values of the modulus of rupture (40,000 psi) and the tensile strength of the iron in the pipe (18,000 psi). These tests shall be made in accordance with dimensions and methods given in the Appendix.

Pipe for these periodic ring and bursting tests shall be so selected that they will be representative of the sizes and various thicknesses of each size cast. Ring tests shall not be made on 3-in. and 4-in. pipe.

Tests of Talbot strips cut from the ring and hardness tests as provided in the Appendix shall be made in conjunction with ring and bursting tests. At least three Talbot strips shall be tested from each burst pipe and one of these strips shall come from the ring. For pipe for which rings less than $10\frac{1}{2}$ in. long are used, the Talbot strip shall come from parts other than the ring.

Tests and records shall include the modulus of rupture of each strip and ring, the modulus of elasticity of each strip and of each ring 12 in. and larger, and a hardness test on all strips.

At the purchaser's request, the manufacturer shall furnish a written transcript of ring and bursting tests and tests on Talbot strips made in connection therewith for a period not exceeding one year and for such sizes as requested.

Sec. 6–19—Additional Tests Required by Purchaser

If more or other tests than those provided in these specifications are required by the purchaser, such tests shall be specified in the invitation for bids.

Sec. 6–20—Defective Specimens and Retests

If any test specimen shows defective machining or lack of continuity of metal, it may be discarded and replaced by another specimen. If any sound test specimen fails to meet the specified requirements, the purchaser may permit a retest on two additional sound specimens from pipe cast in the same period as the specimen which failed; both of the additional specimens shall meet the prescribed tests to be acceptable.

Sec. 6–21—Rejection of Pipe

If any routine chemical analysis fails to meet the chemical requirements of Sec. 6–4.2, or if any acceptance test fails to meet the requirements of Sec. 6–17.1.3, 6–17.2 and 6–20, the pipe cast in the period shall be rejected except as subject to the provisions of Sec. 6–22.

Sec. 6–22—Limiting Rejection

The manufacturer may limit the amount of rejection by making similar additional tests of pipe of the same size as that rejected until the rejected lot is bracketed in order of manufacture by two acceptable tests. If a period is rejected, the acceptability of pipe of different sizes from that rejected may be established by making the routine acceptance tests for these sizes.

APPENDIX

Sec. 6–A1—Talbot Strip Tests

Talbot strips (Fig. 6.1) shall be machined longitudinally from each pipe specimen selected for testing by this method. These Talbot strips may be cut from a part of the ring little stressed in the ring test—i.e., near one of the elements marked *a* in the illustration of the ring test (Fig. 6.2). The strips in any case will be in cross section as indicated in Fig. 6.1—i.e., will have for their width the thickness of the pipe and for their depth 0.50 in. Their length shall be at least $10\frac{1}{2}$ in. These strips shall be tested as beams on supports 10 in. apart with loads applied perpendicularly to the machined faces at two points $3\frac{1}{3}$ in. from the supports. The breaking load and the deflection shall be observed and recorded. For

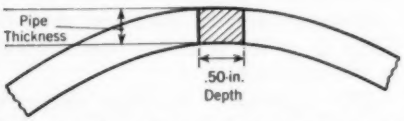

FIG. 6.1. Position From Which Talbot Strip Is Cut

purposes of Sec. 6–6.3—Foundry Records, a Rockwell hardness test at three well distributed points each on the outside of the pipe and on one machined face shall be made and recorded.

The strip shall be accurately calipered at the point of rupture and the modulus of rupture, R, shall be calculated by the usual beam formula, which for this case reduces to the expression:

$$R = \frac{10W}{td^2}$$

The secant modulus of elasticity, E_s, in pounds per square inch, shall be computed by the formula:

$$E_s = \frac{21.3R}{dy}$$

In the above formulas, R is the modulus of rupture (psi), E_s is the secant modulus of elasticity (psi), W is the breaking load (lb), d is the depth (in.) of the strip (intended to be 0.50 in.), t is the width (in.) of the strip (pipe thickness) and y is the deflection (in.) of the strip at the center at breaking load.

Sec. 6–A2—Ring Tests

The maximum length of any ring shall not exceed 12 in.; for pipe 14 in. and larger, the minimum length shall be $10\frac{1}{2}$ in.; for pipe 12 in. and smaller, the minimum length shall be one-half the nominal diameter of the pipe. Each ring shall be tested by the three-edge

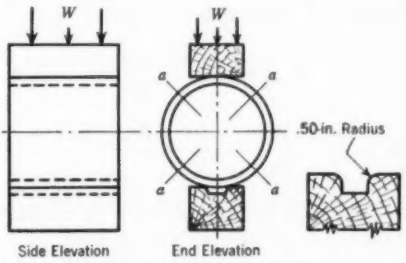

FIG. 6.2. Assembly for Ring Test

bearing method as indicated in Fig. 6.2. The lower bearing for the ring shall consist of two strips with vertical sides having their interior top corners rounded to a radius of approximately $\frac{1}{2}$ in. The strips shall be of hard wood or of metal. If of metal, a piece of fabric or leather approximately $\frac{3}{16}$ in. thick shall be laid over them. They shall be straight and shall be securely fastened to a rigid block with their interior vertical faces the following distances apart:

Nom. Pipe Diam. *in.*	Bearing Strip Spacing *in.*
3–12	$\frac{1}{2}$
14–24	1

The upper bearing shall be an oak block, straight and true from end to end. The upper and lower bearings shall extend the full length of the ring. The ring shall be placed symmetrically between the two bearings, and the center of application of the load shall be so placed that the vertical deformation at the two ends of the ring shall be approximately equal. If the ring is not uniform in thickness, it shall be so placed that the thick and thin portions are near the ends of the horizontal diameter.

A record of the breaking load and the vertical deformation of each ring tested shall be made. The modulus of rupture and modulus of elasticity are computed from the formulas:

$$R = 0.954\frac{W(d+t)}{bt^2}$$

$$E = \frac{0.225W(d+t)^3}{bt^3y} = \frac{0.236R(d+t)^2}{ty}$$

in which R is the modulus of rupture (psi), W is the breaking load (lb), d is the average inside diameter (in.) of the ring, t is the average thickness (in.) of metal along the line of fracture, b is the length (in.) of the ring, E is the modulus of elasticity (psi) and y is the vertical deformation (in.) of the ring at the center.

Sec. 6–A3—Full-Length Bursting Tests

The bursting tensile strength shall be determined by testing full-length pipe (less the amount cut off for ring and strip test specimens) to destruction by hydraulic pressure. Bells may be removed to facilitate testing. A suitable means for holding the end thrust shall be used which will not subject the pipe to endwise tension or compression, or other parasitic stresses. A calibrated pressure gage shall be used for determining the bursting pressure. This gage shall be connected to the interior of the test pipe by a separate connection from that which supplies water for the test. The unit tensile strength in bursting shall be obtained by the use of the formula:

$$S = \frac{Pd}{2t}$$

in which S is the bursting tensile strength (psi) of the iron, P is the internal pressure (psi) at bursting, d is the average inside diameter (in.) of the pipe and t is the minimum average thickness (in.) of the pipe along the principal line of break.

Measurements of thickness shall be taken along the principal line of break at 1-ft intervals.

The minimum average thickness along the principal line of break shall be obtained by averaging the measurements at the thinnest section at a weight of two and at the adjacent sections on each side at a weight of one each; or, if the thinnest section is at the end of the break, by averaging this thinnest-section measurement at a weight of two and the measurements of the adjacent section and the next section at a weight of one each.

Sec. 6–A4—Deflection Measurements

All deflection measurements required by these specifications shall be that of the specimen and shall not include any compression of the supports or loading blocks, or backlash or distortion of the testing machine.

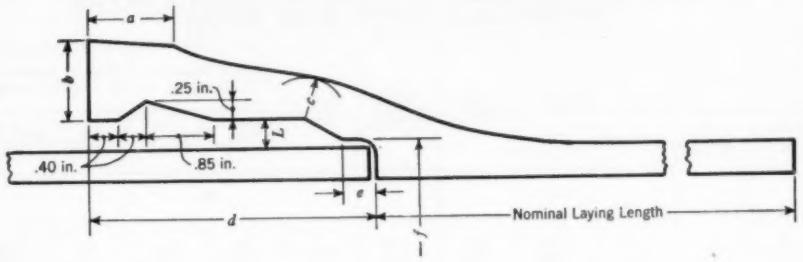

TABLE 6.1

STANDARD DIMENSIONS OF BELLS, SOCKETS AND OUTSIDE DIAMETERS—AND WEIGHTS OF BELLS—OF PIPE CENTRIFUGALLY CAST IN METAL MOLDS

Nom. Diam.	Pipe Thickness		Pipe Outside Diam.	Dimensions of Bells								Bell Weight
				Socket Diam.	Joint Thickness *L*	Socket Depth *d*	Centering Shoulder		*a*	*b*	*c*	
	From	To					Depth *e*	Inside Diam. *f*				
	in.											*lb*
3	0.32	0.38	3.96	4.76	0.40	3.30	0.30	4.10	0.88	1.02	0.41	11
4	0.35	0.44	4.80	5.60	0.40	3.30	0.30	4.94	1.00	1.06	0.47	14
	0.35	0.44	5.00	5.80	0.40	3.30	0.30	5.14	1.00	1.06	0.47	15
6	0.38	0.48	6.90	7.70	0.40	3.88	0.38	7.06	1.13	1.10	0.55	25
	0.38	0.52	7.10	7.90	0.40	3.88	0.38	7.26	1.13	1.10	0.55	26
8	0.41	0.56	9.05	9.85	0.40	4.38	0.38	9.21	1.13	1.28	0.64	41
	0.41	0.60	9.30	10.10	0.40	4.38	0.38	9.46	1.13	1.28	0.64	42
10	0.44	0.60	11.10	11.90	0.40	4.38	0.38	11.28	1.13	1.38	0.69	54
	0.44	0.65	11.40	12.20	0.40	4.38	0.38	11.58	1.13	1.38	0.69	56
12	0.48	0.65	13.20	14.00	0.40	4.38	0.38	13.38	1.13	1.42	0.71	66
	0.48	0.60	13.50	14.30	0.40	4.38	0.38	13.68	1.13	1.42	0.71	67
	0.65	0.76	13.50	14.30	0.40	4.38	0.38	13.68	1.13	1.62	0.81	78
14	0.48	0.69	15.30	16.10	0.40	4.50	0.50	15.52	1.25	1.46	0.73	78
	0.48	0.64	15.65	16.45	0.40	4.50	0.50	15.87	1.25	1.46	0.73	80
	0.69	0.81	15.65	16.45	0.40	4.50	0.50	15.87	1.25	1.76	0.88	101
16	0.50	0.73	17.40	18.40	0.50	4.50	0.50	17.62	1.25	1.54	0.77	96
	0.50	0.68	17.80	18.80	0.50	4.50	0.50	18.02	1.25	1.54	0.77	98
	0.73	0.85	17.80	18.80	0.50	4.50	0.50	18.02	1.25	1.86	0.93	121
18	0.54	0.79	19.50	20.50	0.50	4.50	0.50	19.72	1.25	1.64	0.82	114
	0.54	0.73	19.92	20.92	0.50	4.50	0.50	20.14	1.25	1.64	0.82	116
	0.79	0.92	19.92	20.92	0.50	4.50	0.50	20.14	1.25	1.98	0.99	145
20	0.57	0.84	21.60	22.60	0.50	4.50	0.50	21.82	1.25	1.74	0.87	133
	0.57	0.78	22.06	23.06	0.50	4.50	0.50	22.28	1.25	1.74	0.87	136
	0.84	0.98	22.06	23.06	0.50	4.50	0.50	22.28	1.25	2.10	1.05	171
24	0.63	0.92	25.80	26.80	0.50	4.50	0.50	26.02	1.25	1.94	0.97	179
	0.63	0.85	26.32	27.32	0.50	4.50	0.50	26.54	1.25	1.94	0.97	182
	0.92	1.07	26.32	27.32	0.50	4.50	0.50	26.54	1.25	2.36	1.18	229

TABLE 6.2

STANDARD THICKNESSES, DIAMETERS AND WEIGHTS OF PIPE CENTRIFUGALLY CAST IN METAL MOLDS

Nom. Diam. *in.*	Thickness Class	Thickness	Outside Diam.	Inside Diam.	Barrel Weight Per Foot	Bell Weight	Weight Based on 12-ft Laying Length		Weight Based on 18-ft Laying Length	
							Per Length*	Avg. Per Foot†	Per Length*	Avg. Per Foot†
		in.			*lb*					
3	22	0.32	3.96	3.32	11.4	11	150	12.5	215	12.0
	23	0.35	3.96	3.26	12.4	11	160	13.5	235	13.0
	24	0.38	3.96	3.20	13.3	11	170	14.3	250	13.9
4	22	0.35	4.80	4.10	15.3	14	200	16.6	290	16.1
	23	0.38	4.80	4.04	16.5	14	210	17.7	310	17.3
	24	0.41	4.80	3.98	17.6	14	225	18.8	330	18.4
	25	0.44	4.80	3.92	18.8	14	240	20.0	350	19.5
	22	0.35	5.00	4.30	16.0	15	205	17.2	305	16.9
	23	0.38	5.00	4.24	17.2	15	220	18.5	325	18.0
	24	0.41	5.00	4.18	18.4	15	235	19.7	345	19.2
	25	0.44	5.00	4.12	19.7	15	250	21.0	370	20.5
6	22	0.38	6.90	6.14	24.3	25	315	26.4	460	25.6
	23	0.41	6.90	6.08	26.1	25	340	28.2	495	27.5
	24	0.44	6.90	6.02	27.9	25	360	30.0	525	29.3
	25	0.48	6.90	5.94	30.2	25	385	32.2	570	31.7
	22	0.38	7.10	6.34	25.0	26	325	27.2	475	26.4
	23	0.41	7.10	6.28	26.9	26	350	29.1	510	28.2
	24	0.44	7.10	6.22	28.7	26	370	30.9	545	30.2
	25	0.48	7.10	6.14	31.1	26	400	33.3	585	32.5
	26	0.52	7.10	6.06	33.5	26	430	35.7	630	34.9
8	22	0.41	9.05	8.23	34.7	41	455	38.1	665	36.9
	23	0.44	9.05	8.17	37.1	41	485	40.5	710	39.4
	24	0.48	9.05	8.09	40.3	41	525	43.7	765	42.6
	25	0.52	9.05	8.01	43.5	41	565	46.9	825	45.8
	26	0.56	9.05	7.93	46.6	41	600	50.0	880	48.9
	22	0.41	9.30	8.48	35.7	42	470	39.2	685	38.0
	23	0.44	9.30	8.42	38.2	42	500	41.7	730	40.5
	24	0.48	9.30	8.34	41.5	42	540	45.0	790	43.8
	25	0.52	9.30	8.26	44.8	42	580	48.3	850	47.1
	26	0.56	9.30	8.18	48.0	42	620	51.5	905	50.3
	27	0.60	9.30	8.10	51.2	42	655	54.7	965	53.5
10	22	0.44	11.10	10.22	46.0	54	605	50.5	880	49.0
	23	0.48	11.10	10.14	50.0	54	655	54.5	955	53.0
	24	0.52	11.10	10.06	53.9	54	700	58.4	1025	56.9
	25	0.56	11.10	9.98	57.9	54	750	62.4	1095	60.9
	26	0.60	11.10	9.90	61.8	54	795	66.3	1165	64.8
	22	0.44	11.40	10.52	47.3	56	625	52.0	905	50.4
	23	0.48	11.40	10.44	51.4	56	675	56.1	980	54.5
	24	0.52	11.40	10.36	55.5	56	720	60.2	1055	58.6
	25	0.56	11.40	10.28	59.5	56	770	64.2	1125	62.6
	26	0.60	11.40	10.20	63.5	56	820	68.2	1200	66.6
	27	0.65	11.40	10.10	68.5	56	880	73.2	1290	71.6
12	22	0.48	13.20	12.24	59.8	66	785	65.3	1140	63.4
	23	0.52	13.20	12.16	64.6	66	840	70.1	1230	68.3
	24	0.56	13.20	12.08	69.4	66	900	74.9	1315	73.1
	25	0.60	13.20	12.00	74.1	66	955	79.6	1400	77.8
	26	0.65	13.20	11.90	80.0	66	1025	85.5	1505	83.7
	22	0.48	13.50	12.54	61.3	67	805	66.9	1170	65.0
	23	0.52	13.50	12.46	66.2	67	860	71.8	1260	69.9
	24	0.56	13.50	12.38	71.0	67	920	76.6	1345	74.8
	25	0.60	13.50	12.30	75.9	67	980	81.5	1435	79.7
	26	0.65	13.50	12.20	81.9	78	1060	88.4	1550	86.2
	27	0.70	13.50	12.10	87.8	78	1130	94.3	1660	92.1
	28	0.76	13.50	11.98	94.9	78	1215	101.4	1785	99.2
14	21	0.48	15.30	14.34	69.7	78	915	76.2	1335	74.1
	22	0.51	15.30	14.28	73.9	78	965	80.4	1410	78.2
	23	0.55	15.30	14.20	79.5	78	1030	86.0	1510	83.8
	24	0.59	15.30	14.12	85.1	78	1100	91.6	1610	89.5
	25	0.64	15.30	14.02	92.0	78	1180	98.5	1735	96.5
	26	0.69	15.30	13.92	98.8	78	1265	105.3	1855	103.1

* Including bell. Calculated weight of pipe rounded off to nearest 5 lb.
† Average weight per foot based on calculated weight of pipe before rounding.

TABLE 6.2 (contd.)

STANDARD THICKNESSES, DIAMETERS AND WEIGHTS OF PIPE CENTRIFUGALLY CAST IN METAL MOLDS

Nom. Diam. *in.*	Thickness Class	Thickness	Outside Diam.	Inside Diam.	Barrel Weight Per Foot	Bell Weight	Weight Based on 12-ft Laying Length		Weight Based on 18-ft Laying Length	
							Per Length*	Avg. Per Foot†	Per Length*	Avg. Per Foot†
		in.			*lb*					
14	21	0.48	15.65	14.69	71.4	80	935	78.1	1365	75.8
	22	0.51	15.65	14.63	75.7	80	990	82.4	1445	80.2
	23	0.55	15.65	14.55	81.4	80	1055	88.1	1545	85.8
	24	0.59	15.65	14.47	87.1	80	1125	93.8	1650	91.6
	25	0.64	15.65	14.37	94.2	80	1210	100.9	1775	98.7
	26	0.69	15.65	14.27	101.2	101	1315	109.6	1925	106.9
	27	0.75	15.65	14.15	109.5	101	1415	117.9	2070	115.1
	28	0.81	15.65	14.03	117.8	101	1515	126.2	2220	123.4
16	21	0.50	17.40	16.40	82.8	96	1090	90.8	1585	88.1
	22	0.54	17.40	16.32	89.2	96	1165	97.2	1700	94.5
	23	0.58	17.40	16.24	95.6	96	1245	103.6	1815	100.9
	24	0.63	17.40	16.14	103.6	96	1340	111.6	1960	109.0
	25	0.68	17.40	16.04	111.4	96	1435	119.4	2100	116.8
	26	0.73	17.40	15.94	119.3	96	1530	127.3	2245	124.8
	21	0.50	17.80	16.80	84.8	98	1115	93.0	1625	90.2
	22	0.54	17.80	16.72	91.4	98	1195	99.6	1745	96.9
	23	0.58	17.80	16.64	97.9	98	1275	106.1	1860	103.3
	24	0.63	17.80	16.54	106.0	98	1370	114.2	2005	111.5
	25	0.68	17.80	16.44	114.1	98	1465	122.2	2150	119.5
	26	0.73	17.80	16.34	122.1	121	1585	132.2	2320	128.8
	27	0.79	17.80	16.22	131.7	121	1700	141.8	2490	138.4
	28	0.85	17.80	16.10	141.2	121	1815	151.3	2665	148.0
18	21	0.54	19.50	18.42	100.4	114	1320	109.9	1920	106.7
	22	0.58	19.50	18.34	107.6	114	1405	117.1	2050	113.9
	23	0.63	19.50	18.24	116.5	114	1510	126.0	2210	122.8
	24	0.68	19.50	18.14	125.4	114	1620	134.9	2370	131.8
	25	0.73	19.50	18.04	134.3	114	1725	143.8	2530	140.6
	26	0.79	19.50	17.92	144.9	114	1855	154.4	2720	151.2
	21	0.54	19.92	18.84	102.6	116	1345	112.2	1965	109.1
	22	0.58	19.92	18.76	109.9	116	1435	119.6	2095	116.3
	23	0.63	19.92	18.66	119.1	116	1545	128.8	2260	125.5
	24	0.68	19.92	18.56	128.2	116	1655	137.9	2425	134.8
	25	0.73	19.92	18.46	137.3	116	1765	147.0	2585	143.7
	26	0.79	19.92	18.34	148.1	145	1920	160.2	2810	156.1
	27	0.85	19.92	18.22	158.9	145	2050	171.0	3005	166.9
	28	0.92	19.92	18.08	171.3	145	2200	183.4	3230	179.4
20	21	0.57	21.60	20.46	117.5	133	1545	128.6	2250	124.9
	22	0.62	21.60	20.36	127.5	133	1665	138.6	2430	134.9
	23	0.67	21.60	20.26	137.5	133	1785	148.6	2610	144.9
	24	0.72	21.60	20.16	147.4	133	1900	158.5	2785	154.8
	25	0.78	21.60	20.04	159.2	133	2045	170.3	3000	166.8
	26	0.84	21.60	19.92	170.9	133	2185	182.0	3210	178.4
	21	0.57	22.06	20.92	120.1	136	1575	131.4	2300	127.7
	22	0.62	22.06	20.82	130.3	136	1700	141.6	2480	137.9
	23	0.67	22.06	20.72	140.5	136	1820	151.8	2665	148.1
	24	0.72	22.06	20.62	150.6	136	1945	161.9	2845	158.1
	25	0.78	22.06	20.50	162.7	136	2090	174.0	3065	170.3
	26	0.84	22.06	20.38	174.7	171	2265	188.9	3315	184.1
	27	0.91	22.06	20.24	188.7	171	2435	203.0	3570	198.2
	28	0.98	22.06	20.10	202.5	171	2600	216.8	3815	212.0
24	21	0.63	25.80	24.54	155.4	179	2045	170.3	2975	165.3
	22	0.68	25.80	24.44	167.4	179	2190	182.3	3190	177.3
	23	0.73	25.80	24.34	179.4	179	2330	194.3	3410	189.4
	24	0.79	25.80	24.22	193.7	179	2505	208.6	3665	203.6
	25	0.85	25.80	24.10	207.9	179	2675	222.8	3920	217.8
	26	0.92	25.80	23.96	224.4	179	2870	239.3	4220	234.4
	21	0.63	26.32	25.06	158.6	182	2085	173.8	3035	168.7
	22	0.68	26.32	24.96	170.9	182	2235	186.1	3260	181.0
	23	0.73	26.32	24.86	183.1	182	2380	198.3	3480	193.2
	24	0.79	26.32	24.74	197.7	182	2555	212.9	3740	207.8
	25	0.85	26.32	24.62	212.2	182	2730	227.4	4000	222.3
	26	0.92	26.32	24.48	229.0	229	2975	248.1	4350	241.7
	27	0.99	26.32	24.34	245.8	229	3180	264.9	4655	258.5
	28	1.07	26.32	24.18	264.8	229	3405	283.9	4995	277.5

* Including bell. Calculated weight of pipe rounded off to nearest 5 lb.
† Average weight per foot based on calculated weight of pipe before rounding.

TABLE 6.3—STANDARD THICKNESSES AND WEIGHTS OF PIPE CENTRIFUGALLY CAST IN METAL MOLDS

These thicknesses and weights are for pipe laid without blocks, on flat-bottom trench, with tamped backfill, under 5 ft of cover. For other conditions, see Tables 6.2 and 6.4 hereof and ASA A21.1 (AWWA C101), "Manual for the Computation of Strength and Thickness of Cast Iron Pipe."

Size	Thickness	Outside Diam.	Weight Based on			
			12-ft Laying Length		18-ft Laying Length	
			Avg. Per Foot*	Per Length†	Avg. Per Foot*	Per Length†
in.			*lb*			
Class 50—50-psi Pressure—115-ft Head						
3	0.32	3.96	12.5	150	12.0	215
4	0.35	4.80	16.6	200	16.1	290
6	0.38	6.90	26.4	315	25.6	460
8	0.41	9.05	38.1	455	36.9	665
10	0.44	11.10	50.5	605	49.0	880
12	0.48	13.20	65.3	785	63.4	1140
14	0.48	15.30	76.2	915	74.1	1335
16	0.54	17.40	97.2	1165	94.5	1700
18	0.54	19.50	109.9	1320	106.7	1920
20	0.57	21.60	128.6	1545	124.9	2250
24	0.63	25.80	170.3	2045	165.3	2975
Class 100—100-psi Pressure—231-ft Head						
3	0.32	3.96	12.5	150	12.0	215
4	0.35	4.80	16.6	200	16.1	290
6	0.38	6.90	26.4	315	25.6	460
8	0.41	9.05	38.1	455	36.9	665
10	0.44	11.10	50.5	605	49.0	880
12	0.48	13.20	65.3	785	63.4	1140
14	0.51	15.30	80.4	965	78.2	1410
16	0.54	17.40	97.2	1165	94.5	1700
18	0.58	19.50	117.1	1405	113.9	2050
20	0.62	21.60	138.6	1665	134.9	2430
24	0.68	25.80	182.3	2190	177.3	3190
Class 150—150-psi Pressure—346-ft Head						
3	0.32	3.96	12.5	150	12.0	215
4	0.35	4.80	16.6	200	16.1	290
6	0.38	6.90	26.4	315	25.6	460
8	0.41	9.05	38.1	455	36.9	665
10	0.44	11.10	50.5	605	49.0	880
12	0.48	13.20	65.3	785	63.4	1140
14	0.51	15.65	82.4	990	80.2	1445
16	0.54	17.80	99.6	1195	96.9	1745
18	0.58	19.92	119.6	1435	116.3	2095
20	0.62	22.06	141.6	1700	137.9	2480
24	0.73	26.32	198.3	2380	193.2	3480

* Average weight per foot based on calculated weight of pipe before rounding.
† Including bell. Calculated weight of pipe rounded off to nearest 5 lb.

TABLE 6.3 (contd.)—STANDARD THICKNESSES AND WEIGHTS OF PIPE CENTRIFUGALLY CAST IN METAL MOLDS

These thicknesses and weights are for pipe laid without blocks, on flat-bottom trench, with tamped backfill, under 5 ft of cover. For other conditions, see Tables 6.2 and 6.4 hereof and ASA A21.1 (AWWA C101), "Manual for the Computation of Strength and Thickness of Cast Iron Pipe."

Size	Thickness	Outside Diam.	Weight Based on			
			12-ft Laying Length		18-ft Laying Length	
			Avg. Per Foot*	Per Length†	Avg. Per Foot*	Per Length †
in.			*lb*			
Class 200—200-psi Pressure—462-ft Head						
3	0.32	3.96	12.5	150	12.0	215
4	0.35	4.80	16.6	200	16.1	290
6	0.38	6.90	26.4	315	25.6	460
8	0.41	9.05	38.1	455	36.9	665
10	0.44	11.10	50.5	605	49.0	880
12	0.48	13.20	65.3	785	63.4	1140
14	0.55	15.65	88.1	1055	85.8	1545
16	0.58	17.80	106.1	1275	103.3	1860
18	0.63	19.92	128.8	1545	125.5	2260
20	0.67	22.06	151.8	1820	148.1	2665
24	0.79	26.32	212.9	2555	207.8	3740
Class 250—250-psi Pressure—577-ft Head						
3	0.32	3.96	12.5	150	12.0	215
4	0.35	4.80	16.6	200	16.1	290
6	0.38	6.90	26.4	315	25.6	460
8	0.41	9.05	38.1	455	36.9	665
10	0.44	11.10	50.5	605	49.0	880
12	0.52	13.20	70.1	840	68.3	1230
14	0.59	15.65	93.8	1125	91.6	1650
16	0.63	17.80	114.2	1370	111.5	2005
18	0.68	19.92	137.9	1655	134.8	2425
20	0.72	22.06	161.9	1945	158.1	2845
24	0.79	26.32	212.9	2555	207.8	3740
Class 300—300-psi Pressure—693-ft Head						
3	0.32	3.96	12.5	150	12.0	215
4	0.35	4.80	16.6	200	16.1	290
6	0.38	6.90	26.4	315	25.6	460
8	0.41	9.05	38.1	455	36.9	665
10	0.48	11.10	54.5	655	53.0	955
12	0.52	13.20	70.1	840	68.3	1230
14	0.59	15.65	93.8	1125	91.6	1650
16	0.68	17.80	122.2	1465	119.5	2150
18	0.73	19.92	147.0	1765	143.7	2585
20	0.78	22.06	174.0	2090	170.3	3065
24	0.85	26.32	227.4	2730	222.3	4000

* Average weight per foot based on calculated weight of pipe before rounding.
† Including bell. Calculated weight of pipe rounded off to nearest 5 lb.

TABLE 6.3 (contd.)—STANDARD THICKNESSES AND WEIGHTS OF PIPE CENTRIFUGALLY CAST IN METAL MOLDS

These thicknesses and weights are for pipe laid without blocks, on flat-bottom trench, with tamped backfill, under 5 ft of cover. For other conditions, see Tables 6.2 and 6.4 hereof and ASA A21.1 (AWWA C101), "Manual for the Computation of Strength and Thickness of Cast Iron Pipe."

Size	Thickness	Outside Diam.	Weight Based on			
			12-ft Laying Length		18-ft Laying Length	
			Avg. Per Foot*	Per Length†	Avg. Per Foot*	Per Length†
in.			*lb*			
Class 350—350-psi Pressure—808-ft Head						
3	0.32	3.96	12.5	150	12.0	215
4	0.35	4.80	16.6	200	16.1	290
6	0.38	6.90	26.4	315	25.6	460
8	0.41	9.05	38.1	455	36.9	665
10	0.52	11.10	58.4	700	56.9	1025
12	0.56	13.20	74.9	900	73.1	1315
14	0.64	15.65	100.9	1210	98.7	1775
16	0.68	17.80	122.2	1465	119.5	2150
18	0.79	19.92	160.2	1920	156.1	2810
20	0.84	22.06	188.9	2265	184.1	3315
24	0.92	26.32	248.1	2975	241.7	4350

* Average weight per foot based on calculated weight of pipe before rounding.
† Including bell. Calculated weight of pipe rounded off to nearest 5 lb.

TABLE 6.4

STANDARD THICKNESSES* OF PIPE CENTRIFUGALLY CAST IN METAL MOLDS

Laying Condition A—Flat-Bottom Trench, Without Blocks, Untamped Backfill
Laying Condition B—Flat-Bottom Trench, Without Blocks, Tamped Backfill
Laying Condition C—Pipe Laid on Blocks, Untamped Backfill
Laying Condition D—Pipe Laid on Blocks, Tamped Backfill

Size *in.*	Working Pressure *psi*	3½ ft of Cover				5 ft of Cover				8 ft of Cover			
		Laying Condition				Laying Condition				Laying Condition			
		A	B	C	D	A	B	C	D	A	B	C	D
		Thickness—*in.*											
3	50	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.38	0.32
	100	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.38	0.32
	150	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.38	0.32
	200	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.38	0.32
	250	0.32	0.32	0.32	0.32	0.32	0.32	0.35	0.32	0.32	0.32	0.38	0.32
	300	0.32	0.32	0.32	0.32	0.32	0.32	0.35	0.32	0.32	0.32	0.38	0.32
	350	0.32	0.32	0.32	0.32	0.32	0.32	0.35	0.32	0.32	0.32	0.38	0.32
4	50	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.41	0.35
	100	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.41	0.35
	150	0.35	0.35	0.35	0.35	0.35	0.35	0.38	0.35	0.35	0.35	0.41	0.35
	200	0.35	0.35	0.35	0.35	0.35	0.35	0.38	0.35	0.35	0.35	0.44	0.35
	250	0.35	0.35	0.35	0.35	0.35	0.35	0.38	0.35	0.35	0.35	0.44	0.35
	300	0.35	0.35	0.35	0.35	0.35	0.35	0.38	0.35	0.35	0.35	0.44	0.35
	350	0.35	0.35	0.38	0.35	0.35	0.35	0.38	0.35	0.35	0.35	0.44	0.35
6	50	0.38	0.38	0.41	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.48	0.38
	100	0.38	0.38	0.41	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.48	0.38
	150	0.38	0.38	0.41	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.48	0.38
	200	0.38	0.38	0.41	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.52	0.38
	250	0.38	0.38	0.44	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.52	0.38
	300	0.38	0.38	0.44	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.52	0.38
	350	0.38	0.38	0.44	0.38	0.38	0.38	0.48	0.38	0.38	0.38	0.52	0.38
8	50	0.41	0.41	0.44	0.41	0.41	0.41	0.48	0.41	0.41	0.41	0.52	0.41
	100	0.41	0.41	0.48	0.41	0.41	0.41	0.48	0.41	0.41	0.41	0.56	0.41
	150	0.41	0.41	0.48	0.41	0.41	0.41	0.48	0.41	0.41	0.41	0.56	0.41
	200	0.41	0.41	0.48	0.41	0.41	0.41	0.52	0.41	0.41	0.41	0.56	0.44
	250	0.41	0.41	0.48	0.41	0.41	0.41	0.52	0.41	0.44	0.41	0.56	0.44
	300	0.41	0.41	0.48	0.41	0.41	0.41	0.52	0.41	0.44	0.44	0.60	0.44
	350	0.41	0.41	0.52	0.41	0.44	0.41	0.52	0.44	0.48	0.44	0.60	0.48
10	50	0.44	0.44	0.48	0.44	0.44	0.44	0.52	0.44	0.44	0.44	0.60	0.48
	100	0.44	0.44	0.52	0.44	0.44	0.44	0.52	0.44	0.48	0.44	0.60	0.48
	150	0.44	0.44	0.52	0.44	0.44	0.44	0.56	0.44	0.48	0.44	0.60	0.48
	200	0.44	0.44	0.52	0.44	0.44	0.44	0.56	0.44	0.48	0.48	0.60	0.52
	250	0.44	0.44	0.56	0.44	0.48	0.44	0.56	0.48	0.52	0.48	0.65	0.52
	300	0.48	0.44	0.56	0.48	0.48	0.48	0.56	0.48	0.52	0.52	0.65	0.56
	350	0.48	0.48	0.56	0.48	0.52	0.52	0.60	0.52	0.56	0.52	0.65	0.56
12	50	0.48	0.48	0.52	0.48	0.48	0.48	0.56	0.48	0.52	0.48	0.65	0.52
	100	0.48	0.48	0.56	0.48	0.48	0.48	0.56	0.48	0.52	0.48	0.65	0.52
	150	0.48	0.48	0.56	0.48	0.48	0.48	0.56	0.48	0.52	0.52	0.65	0.56
	200	0.48	0.48	0.56	0.48	0.48	0.48	0.60	0.52	0.56	0.52	0.65	0.56
	250	0.52	0.48	0.60	0.52	0.52	0.52	0.60	0.52	0.56	0.56	0.70	0.60
	300	0.52	0.52	0.60	0.52	0.56	0.52	0.60	0.56	0.60	0.56	0.70	0.60
	350	0.56	0.56	0.60	0.56	0.56	0.56	0.65	0.60	0.60	0.60	0.76	0.65

* Thicknesses include allowances for foundry practice, corrosion, and either water hammer or truck load.

TABLE 6.4 (contd.)

STANDARD THICKNESSES* OF PIPE CENTRIFUGALLY CAST IN METAL MOLDS

Laying Condition A—Flat-Bottom Trench, Without Blocks, Untamped Backfill
Laying Condition B—Flat-Bottom Trench, Without Blocks, Tamped Backfill
Laying Condition C—Pipe Laid on Blocks, Untamped Backfill
Laying Condition D—Pipe Laid on Blocks, Tamped Backfill

Size *in.*	Working Pressure *psi*	3½ ft of Cover				5 ft of Cover				8 ft of Cover			
		Laying Condition				Laying Condition				Laying Condition			
		A	B	C	D	A	B	C	D	A	B	C	D
		Thickness—*in.*											
14	50	0.51	0.48	0.59	0.51	0.51	0.48	0.59	0.55	0.59	0.55	0.69	0.59
	100	0.51	0.48	0.59	0.55	0.55	0.51	0.64	0.55	0.59	0.55	0.69	0.64
	150	0.55	0.51	0.59	0.55	0.55	0.51	0.64	0.59	0.64	0.59	0.75	0.64
	200	0.55	0.51	0.64	0.59	0.55	0.55	0.64	0.59	0.64	0.59	0.75	0.69
	250	0.59	0.55	0.64	0.59	0.59	0.59	0.69	0.59	0.64	0.64	0.75	0.69
	300	0.59	0.59	0.69	0.59	0.64	0.59	0.69	0.64	0.69	0.64	0.81	0.69
	350	0.64	0.64	0.69	0.64	0.64	0.64	0.75	0.69	0.75	0.69	0.81	0.75
16	50	0.54	0.50	0.63	0.58	0.58	0.54	0.63	0.58	0.63	0.58	0.73	0.63
	100	0.54	0.54	0.63	0.58	0.58	0.54	0.68	0.58	0.63	0.58	0.73	0.68
	150	0.58	0.54	0.63	0.58	0.58	0.54	0.68	0.63	0.68	0.63	0.79	0.68
	200	0.58	0.58	0.68	0.63	0.63	0.58	0.68	0.63	0.68	0.63	0.79	0.73
	250	0.63	0.58	0.68	0.63	0.63	0.63	0.73	0.68	0.73	0.68	0.79	0.73
	300	0.63	0.63	0.73	0.68	0.68	0.68	0.73	0.68	0.73	0.73	0.85	0.79
	350	0.68	0.68	0.73	0.68	0.73	0.68	0.79	0.73	0.79	0.73	0.85	0.79
18	50	0.58	0.54	0.63	0.58	0.58	0.54	0.68	0.63	0.68	0.63	0.79	0.68
	100	0.58	0.54	0.68	0.63	0.63	0.58	0.73	0.63	0.68	0.63	0.79	0.73
	150	0.63	0.58	0.68	0.63	0.63	0.58	0.73	0.68	0.73	0.68	0.79	0.73
	200	0.63	0.58	0.73	0.68	0.68	0.63	0.73	0.68	0.73	0.68	0.85	0.79
	250	0.68	0.63	0.73	0.68	0.68	0.68	0.79	0.73	0.79	0.73	0.85	0.79
	300	0.68	0.68	0.79	0.73	0.73	0.73	0.79	0.79	0.79	0.79	0.92	0.85
	350	0.79	0.73	0.79	0.79	0.79	0.79	0.85	0.79	0.85	0.85	0.92	0.85
20	50	0.62	0.57	0.72	0.62	0.67	0.57	0.72	0.67	0.72	0.67	0.78	0.72
	100	0.62	0.57	0.72	0.67	0.67	0.62	0.78	0.67	0.72	0.67	0.84	0.78
	150	0.67	0.62	0.72	0.67	0.67	0.62	0.78	0.72	0.78	0.72	0.84	0.78
	200	0.67	0.62	0.78	0.72	0.72	0.57	0.78	0.72	0.78	0.72	0.91	0.84
	250	0.72	0.67	0.78	0.72	0.78	0.72	0.84	0.78	0.84	0.78	0.91	0.84
	300	0.78	0.72	0.84	0.78	0.78	0.78	0.84	0.84	0.84	0.84	0.98	0.91
	350	0.84	0.78	0.84	0.84	0.84	0.84	0.91	0.84	0.91	0.84	0.98	0.91
24	50	0.68	0.63	0.79	0.68	0.73	0.63	0.79	0.73	0.79	0.73	0.85	0.79
	100	0.73	0.63	0.79	0.73	0.73	0.68	0.85	0.79	0.85	0.73	0.92	0.85
	150	0.73	0.68	0.79	0.79	0.79	0.73	0.85	0.79	0.85	0.79	0.92	0.85
	200	0.79	0.73	0.85	0.79	0.79	0.79	0.92	0.85	0.92	0.85	0.99	0.92
	250	0.79	0.79	0.85	0.85	0.85	0.79	0.92	0.85	0.92	0.85	0.99	0.99
	300	0.85	0.85	0.92	0.85	0.92	0.85	0.99	0.92	0.99	0.92	1.07	0.99
	350	0.92	0.92	0.99	0.92	0.99	0.92	0.99	0.99	1.07	0.99	1.07	1.07

* Thicknesses include allowances for foundry practice, corrosion, and either water hammer or truck load.

UDC 621.774.1

ASA A21.8-1953
(AWWA C108-53)

American Standard Specifications

for

CAST IRON PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS, FOR WATER OR OTHER LIQUIDS

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Incorporated
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NOTE 1—Tables showing additional thicknesses required for greater depths of cover and other conditions of laying will be found in ASA A21.1.

NOTE 2—Users of these tables are cautioned to select fittings having proper socket dimensions and thicknesses suited to the pressures. Pipe specified in these tables have outside diameters which will chamber correctly with existing standards for pipe and fittings.

Users of this document should make reference to "American Recommended Practice Manual for the Computation of Strength and Thickness of Cast Iron Pipe" (ASA A21.1) for complete information concerning the conditions which various thicknesses of pipe are designed to meet. The foreword of the Manual also contains a statement regarding the history of the specifications and references to other related documents.

UDC 621.774.1

ASA A21.8-1953
(AWWA C108-53)

American Standard Specifications for

Cast Iron Pipe Centrifugally Cast in Sand-lined Molds, for Water or Other Liquids

This specification covers cast iron pipe centrifugally cast in sand-lined molds.

Sec. 8–1—Definitions

Purchaser. Wherever the word "purchaser" is used herein, it shall be understood to mean the actual purchaser of the pipe or his authorized agents acting within the scope of the duties entrusted to them.

Heat. A heat is a period during which a cupola or furnace is operated continuously.

Run. A run is a period of one or more shifts during which a shop is operated continuously.

Mixture of Iron. Mixture of iron is a combination of pig iron, scrap, coke and other raw materials charged to a cupola or furnace to give a desired composition of iron; or a combination of molten iron from one or more sources, made in a forehearth or ladle to give a desired composition of iron.

Source of Iron. A source of iron is a cupola, furnace or forehearth from which iron is delivered to a transfer or pouring ladle.

Forehearth. A forehearth is a refractory-lined receptacle for the temporary storage of molten iron from one or more cupolas or furnaces.

Sec. 8–2—Description of Pipe

The pipe shall be made with bell and spigot ends with beads cast on, or with plain ends or such other type of ends as may be agreed upon at the time of purchase. Pipe with bell-and-spigot ends shall conform to the dimensions and weights shown in the tables given in this document. Pipe with other types of ends shall comply with the dimensions agreed upon, but in all other respects shall fulfill the specifications hereinafter given. Pipe shall be straight and shall be true circles in sections, with the inner and outer surfaces concentric. Pipe shall be cast at least 12 ft in nominal laying length. This type of pipe is commonly made at present (1952) in 16-, 16½- and 20-ft lengths.

Sec. 8–3—Casting of Pipe

The pipe shall be centrifugally cast in sand-lined molds and shall remain in the sand for a sufficient length of time to prevent unequal contraction during cooling.

Sec. 8–4—Quality of Iron

8–4.1. All pipe shall be made of cast iron of good quality, and of such

character and so adapted in chemical composition to the thickness of the pipe to be cast, that the iron in the pipe shall be strong, tough, resilient, of even grain and soft enough for satisfactory drilling and cutting, and it shall comply with the physical specifications given in Sec. 8–17 and 8–18. The metal shall be remelted in a cupola or other suitable furnace.

8–4.2. The iron in the pipe shall not contain more than 0.90 per cent of phosphorus nor more than 0.12 per cent of sulphur. Samples for chemical analyses shall be taken by drilling completely through from skin to skin either acceptance test specimens or specimens cast for this purpose, but not to exceed three specimens per heat of approximately eight hours. In case of dispute, analyses will be determined on samples taken from the pipe in question.

Sec. 8–5—Quality of Castings

Pipe shall be smooth, free from scales, lumps, blisters, sand holes, laps and defects of every nature which unfit them for the use for which they are intended. No plugging, filling, burning-in or welding will be allowed except as permitted by the purchaser.

Sec. 8–6—Foundry Records

A record of the results of the following tests shall be made and retained for at least one year. Upon request such record will be available to the purchaser at the foundry. If written transcripts of the results of any of these tests are desired this fact shall be noted in the order for pipe, naming the tests of which transcripts are desired. The methods of testing and the dimensions of all test specimens are given in the Appendix.

8–6.1. *Chemical analyses.* Chemical analyses of each iron mixture used directly in the pouring of pipe, obtained as in Sec. 8–4.2, shall be made for silicon, sulphur, manganese, phosphorus and total carbon during the first hour and at intervals not to exceed three hours throughout the heat. If pipe are poured directly from the cupola, chemical analyses shall be made of iron from the first and from the last ladle. If the mixture is changed one or more times during a heat in order to produce a different iron, the time of taking samples shall be varied in such a way as to obtain representative tests of the iron at least at the beginning and end of each period during which the iron is intended to be constant in quality.

8–6.2. *Pouring temperatures.* The pouring temperature of the iron shall be taken at the casting ladle for each size of pipe at least once each hour.

8–6.3. *Talbot strip tests.* See Sec. 8–17.1.

8–6.4. *Test bar tests.* See Sec. 8–17.2.

8–6.5. *Periodic ring, strip and full-length bursting tests.* See Sec. 8–17 and 8–18.

Sec. 8–7—Marking Pipe

Each pipe shall have the weight and class designation conspicuously painted on it. In addition, each pipe shall have cast on it the manufacturer's mark, the year in which the pipe was cast and, when specified by the purchaser, initials not exceeding four in number. The letters and figures shall be on the outside surface of the pipe, and cast marks shall have dimensions not less than those indicated in the following table:

Nom. Pipe Diam. *in.*	Height of Letter *in.*	Relief of Letter *in.*
3–4	$\frac{1}{2}$	$\frac{1}{16}$
6–12	$\frac{3}{4}$	$\frac{3}{32}$
14–20	$1\frac{1}{2}$	$\frac{1}{4}$
24–48	2	$\frac{1}{8}$

Sec. 8–8—Inspection by Purchaser

8–8.1. *Power of purchaser to inspect.* The purchaser shall have free access at all times to all parts of any manufacturing plant which concern the manufacture of articles to be made for him. He may inspect the material, pattern work, molding, casting, coating and lining of the pipe. The forms, sizes, uniformity and conditions of all pipe herein referred to shall be subject to his inspection and approval, and he may reject, without subjection to hydrostatic test, any pipe which is not in conformity with the specifications or drawings. Any pipe rejected shall be so marked and any marks pertaining to the purchaser shall be chipped or erased from such pipe.

8–8.2. *Manufacturer to furnish men and materials.* The manufacturer shall provide tools, testing equipment, materials, labor and facilities necessary for the required testing, inspection and weighing of the pipe at the foundry.

8–8.3. *Report of purchaser's inspection.* The purchaser shall make written report daily to the foundry office of all pipe rejected with the causes for rejection.

Sec. 8–9—Inspection and Certification by Manufacturer

Should the purchaser have no inspector at the works, the manufacturer shall, if required by the purchaser, furnish a sworn statement that the inspection and all the tests have been made and met as specified. If written transcripts of any of these test results are required, including chemical tests if desired, a request specifying the tests of which transcripts are desired shall accompany the order.

Sec. 8–10—Pipe to Be Delivered Sound

All the pipe shall be delivered in all respects sound and in conformity with these specifications. The inspection shall not relieve the manufacturer of any of his obligations in this respect, and any defective pipe which may have passed the purchaser at the works or elsewhere shall be at all times liable to rejection when discovered, until the final completion and adjustment of the contract; provided, however, that the manufacturer shall not be held liable for pipe found to be damaged after they have been accepted at the agreed point of delivery, unless there shall be unmistakable evidence that the casting was originally defective or damaged before acceptance. Care shall be taken in handling the pipe not to injure the coating or lining, and no pipe or other material of any kind shall be placed in the pipe during transportation or at any other time after they have received the coating or lining.

Sec. 8–11—Cut Pipe

Defective spigot ends on pipe may be cut off in a manner which will produce a square end. Not more than 10 per cent of the total number of pipe of each size of a given order may be shipped as cut pipe. Such cut pipe when cut from 12-ft lengths shall have a nominal laying length of not less than 11 ft; pipe originally of 16-ft or greater length shall not be cut more than 2 ft.

Sec. 8–12—Tolerances or Maximum Permitted Variations

8–12.1. *Pipe and socket diameters.* Outside diameters of pipe barrels and spigot ends, and inside diameters of sockets, shall be kept as nearly as practicable to the specified dimensions. The inside diameters of the sockets and the outside diameters of the spigot ends shall be tested with circular gages. Tolerances or maximum permitted variations from standard dimensions are listed below:

Nom. Pipe Diam. *in.*	Tolerances *in.*
3–12	±0.06
14–24	±0.08
30–36	±0.10
42–48	±0.12

8–12.2. *Thickness.* The minus tolerances from standard thickness of pipe and dimensions *a*, *b*, *c* and *d* of the bells are as follows:

Nom. Pipe Diam. *in.*	Minus Tolerance *in.*
3–8	0.05
10–12	0.06
14–24	0.08
30–48	0.10

Note: In pipe barrel thickness, tolerances 0.02 in. greater than those listed above shall be permissible over areas not exceeding 8 in. in length in any direction.

8–12.3. *Weight.* The weight of no single pipe shall be less than the nominal tabulated weight by more than 5 per cent for pipe 12 in. or smaller in diameter, nor by more than 4 per cent for pipe larger than 12 in. in diameter. The total weight of any order of 25 tons or more shall not be more than 2 per cent under the total nominal weight. The total excess weight to be paid for on orders of 25 tons or more shall not exceed 2 per cent of the nominal weight, and on orders of less than 25 tons shall not exceed 5 per cent of the nominal weight. An order is hereby defined as including all the pipe ordered under the terms of a specific contract or purchase order or a single order placed under the terms of a standing contract. Unless otherwise specified in the contract, a ton shall be 2,000 lb avoirdupois.

Sec. 8–13—Cleaning and Inspecting

All pipe shall have fins and other roughnesses chipped or ground off and shall be thoroughly cleaned, checked as to dimensions and also subjected to a careful inspection and a rolling test, before being coated or lined.

Sec. 8–14—Hydrostatic Test

Each pipe shall be subjected to a hydrostatic proof test. This test may be made either before or after a hot or cold bituminous dip or paint has been applied but shall be made before the cement mortar lining or any other special lining has been applied to pipe for which such lining is specified.

The pipe shall be under the test pressure for at least one-half minute. Any pipe showing defects by leaking, sweating or otherwise shall be rejected. The test pressures shall be in accordance with the table appearing on page 213.

Sec. 8–15—Weighing

Each length of pipe shall be weighed and the weight plainly marked on the outside or inside of the bell or spigot end. Pipe shall be weighed before the application of any lining or coating other than hot or cold bituminous dip or paint.

Table of Hydrostatic Test Pressures

Nom. Pipe Diam. *in.*	Nom. Barrel Thickness *in.*	Test Pressure *psi*
3–12	all thicknesses	500
14	0.57 and less	400
14	0.58 and over	500
16	0.60 and less	400
16	0.61 and over	500
18	0.65 and less	400
18	0.66 and over	500
20	0.70 and less	400
20	0.71 and over	500
24	0.75 and less	400
24	0.76 and over	500
30	0.88 and less	400
30	0.89 and over	500
36	0.98 and less	400
36	0.99 and over	500
42	1.09 and less	400
42	1.10 and over	500
48	1.18 and less	400
48	1.19 and over	500

Sec. 8–16—Linings and Exterior Coatings

Any particular lining or coating which is to be applied to the pipe shall be specified in the agreement made at the time of purchase. Separate specifications for cement-mortar lining (ASA A21.4, also known as AWWA C104), have been provided in connection with specifications for pipe.

No pipe for water works service shall be furnished without protective coating unless specifically ordered by the purchaser.

Sec. 8–17—Acceptance Tests for Physical Properties

The standard acceptance tests for the physical characteristics of the pipe shall be as follows:

Sec. 8–17.1—Talbot Strip Tests

Talbot strip tests shall be used to determine the acceptability of 3-in. to 24-in. pipe for modulus of rupture and secant modulus of elasticity.

17.1.1. *Sampling.* For sampling, every run shall be divided into periods of approximately three hours each, and at least one sample shall be taken during each three-hour period. The sample for the first period of the run shall be taken during the first hour or, if casting is direct from the cupola, from the first ladle. Samples shall be taken so that each size of pipe cast for two hours or longer during the run and each mixture or source of iron used for two hours or longer during the run shall be fairly represented.

17.1.2. *Method of testing.* The method of testing Talbot strips is given in Sec. 8–A1 of the Appendix.

17.1.3. *Acceptance values.* The acceptance values for tests on Talbot strips from 3-in. to 24-in. pipe shall be as follows:

Modulus of rupture: 40,000 psi minimum.

Secant modulus of elasticity: 10,000,000 psi maximum.

If the modulus of elasticity exceeds 10,000,000, the modulus of rupture shall exceed 40,000 in at least the same proportion.

Sec. 8–17.2—Two-Inch Test Bar Tests

ASTM standard (A48 Bar C) 2-in. diameter by 27-in. test bar tests shall be used to determine the acceptability of 30-in. to 48-in. pipe.

From each mixture of iron used to cast pipe of 30-in. to 48-in. sizes, 2-in. diameter test bars shall be cast and tested from the first ladle of iron, and at intervals not to exceed three hours during the heat.

For the record, from every 200 lengths, but from at least one pipe of each size each week, one Talbot strip shall be cut and tested, and shall meet the requirements of Sec. 8–17.1.3.

At the manufacturer's option, Talbot strips may be tested instead of test bars. If Talbot strips are tested, they shall meet the requirements of Sec. 8–17.1.3.

Test bars shall have a minimum breaking load of 6,000 lb and a deflection of 0.15 in. plus 0.01 in. for each 500 lb that the breaking load exceeds 6,000 lb.

These test bar values apply only to thickness classes 21 to 25 in pipe designed with an 18,000-psi tensile strength in bursting and a 40,000-psi modulus of rupture of the ring.

Sec. 8–18—Periodic Ring Tests and Full-Length Bursting Tests

The manufacturer shall periodically make such bursting tests and ring tests in conjunction with strip tests that he can certify the design values of the modulus of rupture (40,000 psi) and the tensile strength of the iron in the pipe (18,000 psi). These tests shall be made in accordance with dimensions and methods given in the Appendix.

Pipe for these periodic ring and bursting tests shall be so selected that they will be representative of the sizes and various thicknesses of each size cast. Ring tests shall not be made on 3-in. and 4-in. pipe.

Tests of Talbot strips cut from the ring, as provided in the Appendix, shall be made in conjunction with ring and bursting tests. At least three Talbot strips shall be tested from each burst pipe and one of these strips shall come from the ring. For pipe for which rings less than 10½ in. long are used, the Talbot strip shall come from parts other than the ring.

Tests and records shall include the modulus of rupture of each strip and ring and also the modulus of elasticity of each strip and of each ring 12 in. and larger; the breaking load and deflection of each test bar shall also be included.

At the purchaser's request, the manufacturer shall furnish a written transcript of ring and bursting tests and tests on Talbot strips made in connection therewith for a period not exceeding one year and for such sizes as requested.

Unless there is a record of satisfactory tests equivalent to those hereinafter described, extending to within three months or less of the time to begin manufacture of an order for pipe of any size from 30 in. to 48 in., the producer shall test three pipe from the first day's production and one each succeeding day for the next four days. If all the tests meet the specifications, he shall test one pipe every five days for the next three weeks, and if all those meet the specifications, he shall test one pipe each month. In the case of a failure of any test, the same series of tests as above specified shall be repeated. If there is a lapse of more than one month in the manufacture of such pipe, the monthly test shall be made on a pipe from the first day's run. If the tests are all satisfactory, the number of pipe tested shall not exceed 3 per cent of the order.

Sec. 8–19—Additional Tests Required by Purchaser

If more or other tests than those provided in these specifications are required by the purchaser, such tests

shall be specified in the invitation for bids.

Sec. 8–20—Defective Specimens and Retests

8–20.1. If any test specimen shows defective machining or lack of continuity of metal, it may be discarded and replaced by another specimen. If any sound test specimen fails to meet the specified requirements, the purchaser may permit a retest on two additional sound specimens from pipe cast in the same period as the specimen which failed; both of the additional specimens shall meet the prescribed tests to be acceptable.

8–20.2. Test bars may be cast in pairs and at least one bar from each pair shall be tested, but the manufacturer shall have the right to test both bars, in which case the better bar shall be taken as representative.

8–20.3. If a routine test bar test fails to meet the requirements, the manufacturer shall have the right to substitute two Talbot strips cut from a pipe cast with iron represented by the failed test bar test. If both strip tests meet the requirements, the pipe for that period shall be acceptable.

Sec. 8–21—Rejection of Pipe

If any routine chemical analysis fails to meet the chemical requirements of Sec. 8–4.2, or if any acceptance test fails to meet the requirements of Sec. 8–17.1.3, 8–17.2 and 8–20, the pipe cast in the period shall be rejected except as subject to the provisions of Sec. 8–22.

Sec. 8–22—Limiting Rejection

The manufacturer may limit the amount of rejection by making similar additional tests of pipe of the same size as that rejected until the rejected lot is bracketed in order of manufacture by two acceptable tests. If a period is rejected, the acceptability of pipe of different sizes from that rejected may be established by making the routine acceptance tests for these sizes.

Appendix *

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Sec. 8-A1—Talbot Strip Tests

Sec. 8-A2—Ring Tests

Sec. 8-A3—Full-Length Bursting Tests

Sec. 8-A4—Test Bars

Sec. 8-A5—Deflection Measurements

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Table 8.1—Standard Dimensions of Bells, Sockets, Spigot Beads and Outside Diameters—and Weights of Bells and Spigot Beads—of Pipe Centrifugally Cast in Sand-lined Molds.

Table 8.2—Standard Thicknesses, Diameters and Weights of Pipe Centrifugally Cast in Sand-lined Molds.

Table 8.3—Standard Thicknesses and Weights of Pipe Centrifugally Cast in Sand-lined Molds.

Table 8.4—Standard Thicknesses of Pipe Centrifugally Cast in Sand-lined Molds.

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* This Appendix is a part of ASA A21.8—American Standard Specifications for Cast Iron Pipe Centrifugally Cast in Sand-lined Molds, for Water or Other Liquids.

† Data on thicknesses required for greater depths of cover and conditions of laying other than those assumed in the following tables will be found in Appendix B of ASA A21.1—American Recommended Practice Manual for the Computation of Strength and Thickness of Cast Iron Pipe.

Users of the following tables are cautioned to select fittings having proper socket dimensions and thicknesses suited to the pressures. Pipe specified in these tables have outside diameters which will chamber correctly with existing standards for pipe and fittings.

Sec. 8–A1—Talbot Strip Tests

Talbot strips (Fig. 8.1) shall be machined longitudinally from each pipe specimen selected for testing by this method. These Talbot strips may be cut from a part of the ring little stressed in the ring test—i.e., near one of the elements marked *a* in the illustration of the ring test (Fig. 8.2). The strips in any case will be in cross section as indicated in Fig. 8.1—i.e., will have for their width the thickness of the pipe and for their depth, 0.50 in. Their length shall be at least $10\frac{1}{2}$ in. These strips shall be tested as beams on supports 10 in. apart with loads applied perpendicularly to the machined faces at two points $3\frac{1}{3}$ in. from the supports. The breaking load and

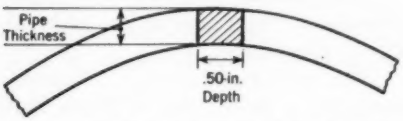


FIG. 8.1. Position From Which Talbot Strip Is Cut

the deflection shall be observed and recorded.

The strip shall be accurately calipered at the point of rupture and the modulus of rupture, R, shall be calculated by the usual beam formula, which for this case reduces to the expression:

$$R = \frac{10\,W}{td^2}$$

The secant modulus of elasticity, E_s, in pounds per square inch, shall be computed by the formula:

$$E_s = \frac{21.3R}{dy}$$

In the above formulas, R is the modulus of rupture (psi), E_s is the secant modulus of elasticity (psi), W is the breaking load (lb), d is the depth (in.) of the strip (intended to be 0.50 in.), t is the width (in.) of the strip (pipe thickness) and y is the deflection (in.) of the strip at the center at breaking load.

Sec. 8–A2—Ring Tests

The maximum length of any ring shall not exceed 12 in.; for pipe 14 in. and larger, the minimum length shall be $10\frac{1}{2}$ in.; for pipe 12 in. and smaller, the minimum length shall be one-half the nominal diameter of the pipe. Each ring shall be tested by the three-edge bearing method as indicated in Fig. 8.2.

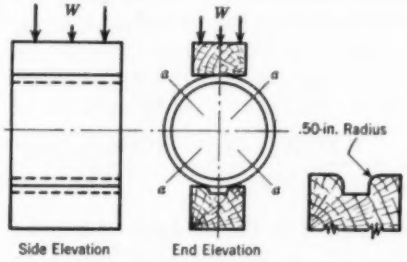


FIG. 8.2. Assembly for Ring Test

The lower bearing for the ring shall consist of two strips with vertical sides having their interior top corners rounded to a radius of approximately $\frac{1}{2}$ in. The strips shall be of hard wood or of metal. If of metal, a piece of fabric or leather approximately $\frac{3}{16}$ in. thick shall be laid over them. They shall be straight and shall be securely fastened to a rigid block, with their interior vertical faces the following distances apart:

Nom. Pipe Diam. *in.*	Bearing Strip Spacing *in.*
3–12	$\frac{1}{2}$
14–24	1
30–48	2

The upper bearing shall be an oak block, straight and true from end to end. The upper and lower bearings shall extend the full length of the ring. The ring shall be placed symmetrically between the two bearings, and the center of application of the load shall be so placed that the vertical deformation at the two ends of the ring shall be approximately equal. If the ring is not uniform in thickness, it shall be so placed that the thick and thin portions are near the ends of the horizontal diameter.

A record of the breaking load and the vertical deformation of each ring tested shall be made. The modulus of rupture and modulus of elasticity are computed from the formulas:

$$R = 0.954 \frac{W(d + t)}{bt^2}$$

$$E = \frac{0.225W(d + t)^3}{bt^3y} = \frac{0.236R(d + t)^2}{ty}$$

in which R is the modulus of rupture (psi), W is the breaking load (lb), d is the average inside diameter (in.) of the ring, t is the average thickness (in.) of metal along the line of fracture, b is the length (in.) of the ring, E is the modulus of elasticity (psi) and y is the vertical deformation (in.) of the ring at the center.

Sec. 8–A3—Full-Length Bursting Tests

The bursting tensile strength shall be determined by testing full-length pipe (less the amount cut off for ring and strip test specimens) to destruction by hydraulic pressure. Bells may be removed to facilitate testing. A suitable means for holding the end thrust shall be used which will not subject the pipe to endwise tension or compression, or other parasitic stresses. A calibrated pressure gage shall be used for determining the bursting pressure. This gage shall be connected to the interior of the test pipe by a separate connection from that which supplies water for the test. The unit tensile strength in bursting shall be obtained by the use of the formula:

$$S = \frac{Pd}{2t}$$

in which S is the bursting tensile strength (psi) of the iron, P is the internal pressure (psi) at bursting, d is the average inside diameter (in.) of the pipe and t is the minimum average thickness (in.) of the pipe along the principal line of break.

Measurements of thickness shall be taken along the principal line of break at 1-ft intervals.

The minimum average thickness along the principal line of break shall be obtained by averaging the measurements at the thinnest section at a weight of two and at the adjacent sections on each side at a weight of one each; or, if the thinnest section is at the end of the break, by averaging this thinnest-section measurement at a weight of two and the measurements of the adjacent section and the next section at a weight of one each.

Sec. 8–A4—Test Bars

8–A4.1. *Dimensions.* Test bars for pipe of 30-in. to 48-in. diameter shall be 2 in. in diameter and not less than 26 in. long. Individual test bars may vary as much as 3 per cent from the standard diameter.

8–A4.2. *Method of casting.* The bars shall be cast vertically in well faced, dry sand molds provided with

a suitable pouring basin and mounted on a suitable refractory foundation. Metal for the bars shall be obtained by using a small heated ladle taking its metal from the main ladle from which the pipe is to be poured. The metal shall be taken after all alloys and other additional metal, except cast-iron pipe scrap for cooling, have been added to the main ladle and become melted. The bars shall not be removed from the mold before they have cooled to 500°F.

8–A4.3. *Method of testing.* The bars shall be broken as beams by placing them on supports 24 in. apart and applying the load at the center of the span. The breaking load and the corresponding deflection shall be observed and recorded.

8–A4.4. *Correcting observed breaking loads and deflections.* The bars shall be measured at the point of application of the load and the results corrected to standard dimensions by the conventional beam formula (for bars of 2-in. diameter):

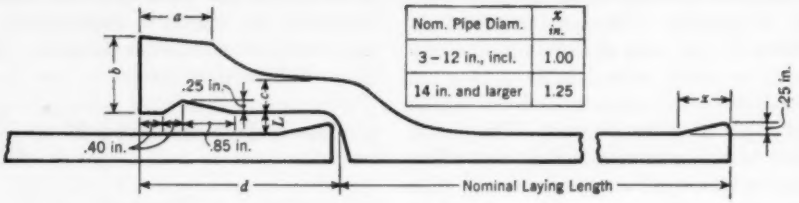
$$\text{Corrected } W = \text{Observed } W \times \frac{8}{d_h d_v^2}$$

$$\text{Corrected } y = \text{Observed } y \times \frac{d_v}{2}$$

in which W is the breaking load (lb), d_h is the measured horizontal diameter (in.), d_v is the measured vertical diameter (in.) and y is the deflection (in.) at breaking.

Sec. 8–A5—Deflection Measurements

All deflection measurements required by these specifications shall be that of the specimen and shall not include any compression of the supports or loading blocks, or backlash or distortion of the testing machine.



Nom. Pipe Diam.	x in.
3 – 12 in., incl.	1.00
14 in. and larger	1.25

TABLE 8.1

STANDARD DIMENSIONS OF BELLS, SOCKETS, SPIGOT BEADS AND OUTSIDE DIAMETERS—AND WEIGHTS OF BELLS AND SPIGOT BEADS—OF PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

Nom. Diam.	Pipe Thickness		Pipe Outside Diam.	Dimensions of Bells						Weight of Bell and Spigot Bead
	From	To		Socket Diam.	Thickness of Joint *L*	Socket Depth *d*	*a*	*b*	*c*	
	in.									*lb*
3	0.32	0.38	3.96	4.76	0.40	3.50	1.25	1.25	0.52	15
4	0.35	0.44	4.80	5.60	0.40	3.50	1.25	1.30	0.55	19
	0.35	0.44	5.00	5.80	0.40	3.50	1.25	1.30	0.55	20
6	0.38	0.41	6.90	7.70	0.40	3.50	1.38	1.35	0.48	26
	0.44	0.48	6.90	7 70	0.40	3.50	1.38	1.35	0.64	29
	0.38	0.41	7.10	7.90	0.40	3.50	1.38	1.35	0.48	27
	0.44	0.52	7.10	7.90	0.40	3.50	1.38	1.35	0.64	30
8	0.41	0.44	9.05	9.85	0.40	4.00	1.38	1.45	0.52	37
	0.48	0.56	9.05	9.85	0.40	4.00	1.38	1.45	0.68	43
	0.41	0.44	9.30	10.10	0.40	4.00	1.38	1.45	0.52	38
	0.48	0.60	9.30	10.10	0.40	4.00	1.38	1.45	0.68	44
10	0.44	0.48	11.10	11.90	0.40	4.00	1.50	1.55	0.56	50
	0.52	0.60	11.10	11.90	0.40	4.00	1.50	1.55	0.73	56
	0.44	0.48	11.40	12.20	0.40	4.00	1.50	1.55	0.56	51
	0.52	0.65	11.40	12.20	0.40	4.00	1.50	1.55	0.73	58
12	0.48	0.52	13.20	14.00	0.40	4.00	1.50	1.60	0.60	63
	0.56	0.65	13.20	14.00	0.40	4.00	1.50	1.60	0.79	71
	0.48	0.52	13.50	14.30	0.40	4.00	1.50	1.60	0.60	64
	0.56	0.70	13.50	14.30	0.40	4.00	1.50	1.60	0.79	73
	0.76		13.50	14.30	0.40	4.00	1.50	1.60	0.95	81
14	0.48	0.55	15.30	16.10	0.40	4.00	1.50	1.70	0.64	79
	0.59	0.69	15.30	16.10	0.40	4.00	1.50	1.70	0.85	88
	0.48	0.55	15.65	16.45	0.40	4.00	1.50	1.70	0.64	80
	0.59	0.75	15.65	16.45	0.40	4.00	1.50	1.70	0.85	90
	0.81		15.65	16.45	0.40	4.00	1.50	1.70	1.01	99

TABLE 8.1 (contd.)

STANDARD DIMENSIONS OF BELLS, SOCKETS, SPIGOT BEADS AND OUTSIDE DIAMETERS—AND WEIGHTS OF BELLS AND SPIGOT BEADS—OF PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

Nom. Diam.	Pipe Thickness		Pipe Outside Diam.	Dimensions of Bells						Weight of Bell and Spigot Bead
	From	To		Socket Diam.	Thickness of Joint *L*	Socket Depth *d*	*a*	*b*	*c*	
	in.									lb
16	0.50	0.58	17.40	18.40	0.50	4.00	1.75	1.75	0.67	96
	0.63	0.73	17.40	18.40	0.50	4.00	1.75	1.75	0.89	108
	0.50	0.58	17.80	18.80	0.50	4.00	1.75	1.75	0.67	98
	0.63	0.79	17.80	18.80	0.50	4.00	1.75	1.75	0.89	110
	0.85		17.80	18.80	0.50	4.00	1.75	1.75	1.06	122
18	0.54	0.63	19.50	20.50	0.50	4.00	1.75	1.80	0.72	115
	0.68	0.79	19.50	20.50	0.50	4.00	1.75	1.80	0.95	128
	0.54	0.63	19.92	20.92	0.50	4.00	1.75	1.80	0.72	117
	0.68	0.85	19.92	20.92	0.50	4.00	1.75	1.80	0.95	130
	0.92		19.92	20.92	0.50	4.00	1.75	1.80	1.14	145
20	0.57	0.67	21.60	22.60	0.50	4.00	1.75	1.90	0.76	135
	0.72	0.84	21.60	22.60	0.50	4.00	1.75	1.90	1.01	149
	0.57	0.67	22.06	23.06	0.50	4.00	1.75	1.90	0.76	137
	0.72	0.91	22.06	23.06	0.50	4.00	1.75	1.90	1.01	152
	0.98		22.06	23.06	0.50	4.00	1.75	1.90	1.21	171
24	0.63	0.73	25.80	26.80	0.50	4.00	2.00	2.05	0.85	171
	0.79	0.92	25.80	26.80	0.50	4.00	2.00	2.05	1.04	191
	0.63	0.73	26.32	27.32	0.50	4.00	2.00	2.05	0.85	174
	0.79	0.92	26.32	27.32	0.50	4.00	2.00	2.05	1.04	194
	0.99	1.07	26.32	27.32	0.50	4.00	2.00	2.05	1.29	221
30	0.73	0.85	32.00	33.00	0.50	4.50	2.00	2.25	0.97	254
	0.92	1.07	32.00	33.00	0.50	4.50	2.00	2.25	1.20	280
	1.16		32.00	33.00	0.50	4.50	2.00	2.25	1.49	318
36	0.81	0.94	38.30	39.30	0.50	4.50	2.00	2.45	1.09	347
	1.02	1.19	38.30	39.30	0.50	4.50	2.00	2.45	1.35	390
	1.29	1.39	38.30	39.30	0.50	4.50	2.00	2.45	1.67	445
42	0.90	1.05	44.50	45.50	0.50	5.00	2.00	2.65	1.20	450
	1.13	1.32	44.50	45.50	0.50	5.00	2.00	2.65	1.48	510
	1.43	1.54	44.50	45.50	0.50	5.00	2.00	2.65	1.83	585
48	0.98	1.14	50.80	51.80	0.50	5.00	2.00	2.85	1.29	556
	1.23	1.44	50.80	51.80	0.50	5.00	2.00	2.85	1.61	634
	1.56	1.68	50.80	51.80	0.50	5.00	2.00	2.85	1.99	735

TABLE 8.2

STANDARD THICKNESSES, DIAMETERS AND WEIGHTS OF PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

Nom. Diam. *in.*	Thickness Class	Thickness *in.*	Outside Diam. *in.*	Inside Diam. *in.*	Weight of Barrel per Foot *lb*	Weight of Bell and Spigot Bead *lb*	Weight (*lb*) Based on					
							16-ft Laying Length		16½-ft Laying Length		20-ft Laying Length	
							Per Length*	Avg. per Foot†	Per Length*	Avg. per Foot†	Per Length*	Avg. per Foot†
3	22	0.32	3.96	3.32	11.4	15	195	12.4	205	12.3		
	23	0.35	3.96	3.26	12.4	15	215	13.4	220	13.3		
	24	0.38	3.96	3.20	13.3	15	230	14.3	235	14.2		
4	22	0.35	4.80	4.10	15.3	19	265	16.5	270	16.4		
	23	0.38	4.80	4.04	16.5	19	285	17.7	290	17.6		
	24	0.41	4.80	3.98	17.6	19	300	18.8	310	18.7		
	25	0.44	4.80	3.92	18.8	19	320	20.0	330	19.9		
	22	0.35	5.00	4.30	16.0	20	275	17.2	285	17.1		
	23	0.38	5.00	4.24	17.2	20	295	18.5	305	18.4		
	24	0.41	5.00	4.18	18.4	20	315	19.7	325	19.6		
	25	0.44	5.00	4.12	19.7	20	335	21.0	345	20.9		
6	22	0.38	6.90	6.14	24.3	26	415	25.9	425	25.8		
	23	0.41	6.90	6.08	26.1	26	445	27.7	455	27.6		
	24	0.44	6.90	6.02	27.9	29	475	29.7	490	29.6		
	25	0.48	6.90	5.94	30.2	29	510	32.0	525	31.9		
	22	0.38	7.10	6.34	25.0	27	425	26.7	440	26.6		
	23	0.41	7.10	6.28	26.9	27	455	28.5	470	28.4		
	24	0.44	7.10	6.22	28.7	30	490	30.6	505	30.5		
	25	0.48	7.10	6.14	31.1	30	530	33.0	545	32.9		
	26	0.52	7.10	6.06	33.5	30	565	35.4	585	35.3		
8	22	0.41	9.05	8.23	34.7	37	590	37.0	610	36.9		
	23	0.44	9.05	8.17	37.1	37	630	39.5	650	39.4		
	24	0.48	9.05	8.09	40.3	43	690	43.0	710	42.9		
	25	0.52	9.05	8.01	43.5	43	740	46.2	760	46.1		
	26	0.56	9.05	7.93	46.6	43	790	49.3	810	49.2		
	22	0.41	9.30	8.48	35.7	38	610	38.1	625	38.0		
	23	0.44	9.30	8.42	38.2	38	650	40.6	670	40.5		
	24	0.48	9.30	8.34	41.5	44	710	44.3	730	44.2		
	25	0.52	9.30	8.26	44.8	44	760	47.6	785	47.5		
	26	0.56	9.30	8.18	48.0	44	810	50.7	835	50.6		
	27	0.60	9.30	8.10	51.2	44	865	54.0	890	53.9		

* Including bell and spigot bead. Calculated weight of pipe rounded off to nearest 5 lb.
† Average weight per foot based on calculated weight of pipe before rounding.

† Average weight per foot based on calculated weight of pipe before rounding.

TABLE 8.2 (contd.)

STANDARD THICKNESSES, DIAMETERS AND WEIGHTS OF PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

Nom. Diam. *in.*	Thickness Class	Thickness *in.*	Outside Diam. *in.*	Inside Diam. *in.*	Weight of Barrel per Foot *lb*	Weight of Bell and Spigot Bead *lb*	Weight (*lb*) Based on					
							16-ft Laying Length		16½-ft Laying Length		20-ft Laying Length	
							Per Length*	Avg. per Foot†	Per Length*	Avg. per Foot†	Per Length*	Avg. per Foot†
10	22	0.44	11.10	10.22	46.0	50	785	49.1	810	49.0		
	23	0.48	11.10	10.14	50.0	50	850	53.1	875	53.0		
	24	0.52	11.10	10.06	53.9	56	920	57.4	945	57.3		
	25	0.56	11.10	9.98	57.9	56	980	61.4	1,010	61.3		
	26	0.60	11.10	9.90	61.8	56	1,045	65.3	1,075	65.2		
	22	0.44	11.40	10.52	47.3	51	810	50.5	830	50.4		
	23	0.48	11.40	10.44	51.4	51	875	54.6	900	54.5		
	24	0.52	11.40	10.36	55.5	58	945	59.1	975	59.0		
	25	0.56	11.40	10.28	59.5	58	1,010	63.1	1,040	63.0		
	26	0.60	11.40	10.20	63.5	58	1,075	67.1	1,105	67.0		
	27	0.65	11.40	10.10	68.5	58	1,155	72.1	1,190	72.0		
12	22	0.48	13.20	12.24	59.8	63	1,020	63.7	1,050	63.6	1,260	63.0
	23	0.52	13.20	12.16	64.6	63	1,095	68.5	1,130	68.4	1,355	67.8
	24	0.56	13.20	12.08	69.4	71	1,180	73.8	1,215	73.7	1,460	73.0
	25	0.60	13.20	12.00	74.1	71	1,255	78.5	1,295	78.4	1,555	77.7
	26	0.65	13.20	11.90	80.0	71	1,350	84.4	1,390	84.3	1,670	83.6
	22	0.48	13.50	12.54	61.3	64	1,045	65.3	1,075	65.2	1,290	64.5
	23	0.52	13.50	12.46	66.2	64	1,125	70.2	1,155	70.1	1,390	69.4
	24	0.56	13.50	12.38	71.0	73	1,210	75.6	1,245	75.4	1,495	74.7
	25	0.60	13.50	12.30	75.9	73	1,285	80.4	1,325	80.3	1,590	79.6
	26	0.65	13.50	12.20	81.9	73	1,385	86.5	1,425	86.3	1,710	85.6
	27	0.70	13.50	12.10	87.8	73	1,480	92.4	1,520	92.2	1,830	91.4
	28	0.76	13.50	11.98	94.9	81	1,600	100.0	1,645	99.7	1,980	99.0
14	21	0.48	15.30	14.34	69.7	79	1,195	74.6	1,230	74.5	1,475	73.7
	22	0.51	15.30	14.28	73.9	79	1,260	78.8	1,300	78.7	1,555	77.8
	23	0.55	15.30	14.20	79.5	79	1,350	84.4	1,390	84.3	1,670	83.4
	24	0.59	15.30	14.12	85.1	88	1,450	90.6	1,490	90.4	1,790	89.4
	25	0.64	15.30	14.02	92.0	88	1,560	97.5	1,605	97.3	1,930	96.4
	26	0.69	15.30	13.92	98.8	88	1,670	104.3	1,720	104.1	2,065	103.2
	21	0.48	15.65	14.69	71.4	80	1,220	76.4	1,260	76.3	1,510	75.4
	22	0.51	15.65	14.63	75.7	80	1,290	80.7	1,330	80.5	1,595	79.7
	23	0.55	15.65	14.55	81.4	80	1,380	86.4	1,425	86.3	1,710	85.4
	24	0.59	15.65	14.47	87.1	90	1,485	92.7	1,525	92.5	1,830	91.5
	25	0.64	15.65	14.37	94.2	90	1,595	99.8	1,645	99.7	1,975	98.7
	26	0.69	15.65	14.27	101.2	90	1,710	106.8	1,760	106.7	2,115	105.7
	27	0.75	15.65	14.15	109.5	90	1,840	115.1	1,895	114.9	2,280	114.0
	28	0.81	15.65	14.03	117.8	99	1,985	124.0	2,045	123.8	2,455	122.8

* Including bell and spigot bead. Calculated weight of pipe rounded off to nearest 5 lb.
† Average weight per foot based on calculated weight of pipe before rounding.

TABLE 8.2 (contd.)

STANDARD THICKNESSES, DIAMETERS AND WEIGHTS OF PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

Nom. Diam. *in.*	Thickness Class	Thickness *in.*	Outside Diam. *in.*	Inside Diam. *in.*	Weight of Barrel per Foot *lb*	Weight of Bell and Spigot Bead *lb*	Weight (*lb*) Based on					
							16-ft Laying Length		16½-ft Laying Length		20-ft Laying Length	
							Per Length*	Avg. per Foot†	Per Length*	Avg. per Foot†	Per Length*	Avg. per Foot†
16	21	0.50	17.40	16.40	82.8	96	1,420	88.8	1,460	88.6	1,750	87.6
	22	0.54	17.40	16.32	89.2	96	1,525	95.2	1,570	95.0	1,880	94.0
	23	0.58	17.40	16.24	95.6	96	1,625	101.6	1,675	101.4	2,010	100.4
	24	0.63	17.40	16.14	103.6	108	1,765	110.4	1,815	110.1	2,180	108.9
	25	0.68	17.40	16.04	111.4	108	1,890	118.2	1,945	117.9	2,335	116.7
	26	0.73	17.40	15.94	119.3	108	2,015	126.0	2,075	125.8	2,495	124.7
	21	0.50	17.80	16.80	84.8	98	1,455	90.9	1,495	90.7	1,795	89.7
	22	0.54	17.80	16.72	91.4	98	1,560	97.5	1,605	97.3	1,925	96.3
	23	0.58	17.80	16.64	97.9	98	1,665	104.0	1,715	103.8	2,055	102.8
	24	0.63	17.80	16.54	106.0	110	1,805	112.9	1,860	112.7	2,230	111.4
	25	0.68	17.80	16.44	114.1	110	1,935	121.0	1,995	120.8	2,390	119.4
	26	0.73	17.80	16.34	122.1	110	2,065	129.0	2,125	128.8	2,550	127.6
	27	0.79	17.80	16.22	131.7	110	2,215	138.5	2,285	138.4	2,745	137.2
	28	0.85	17.80	16.10	141.2	122	2,380	148.8	2,450	148.6	2,945	147.3
18	21	0.54	19.50	18.42	100.4	115	1,720	107.6	1,770	107.4	2,125	106.2
	22	0.58	19.50	18.34	107.6	115	1,835	114.8	1,890	114.6	2,265	113.3
	23	0.63	19.50	18.24	116.5	115	1,980	123.7	2,035	123.4	2,445	122.2
	24	0.68	19.50	18.14	125.4	128	2,135	133.4	2,195	133.1	2,635	131.7
	25	0.73	19.50	18.04	134.3	128	2,275	142.3	2,345	142.1	2,815	140.7
	26	0.79	19.50	17.92	144.9	128	2,445	152.9	2,520	152.7	3,025	151.3
	21	0.54	19.92	18.84	102.6	117	1,760	109.9	1,810	109.7	2,170	108.4
	22	0.58	19.92	18.76	109.9	117	1,875	117.2	1,930	117.0	2,315	115.8
	23	0.63	19.92	18.66	119.1	117	2,025	126.5	2,080	126.2	2,500	125.0
	24	0.68	19.92	18.56	128.2	130	2,180	136.3	2,245	136.1	2,695	134.7
	25	0.73	19.92	18.46	137.3	130	2,325	145.4	2,395	145.2	2,875	143.7
	26	0.79	19.92	18.34	148.1	130	2,500	156.2	2,575	156.1	3,090	154.6
	27	0.85	19.92	18.22	158.9	130	2,670	167.0	2,750	166.8	3,310	165.4
	28	0.92	19.92	18.08	171.3	145	2,885	180.4	2,970	180.1	3,570	178.6
20	21	0.57	21.60	20.46	117.5	135	2,015	125.9	2,075	125.7	2,485	124.2
	22	0.62	21.60	20.36	127.5	135	2,175	135.9	2,240	135.7	2,685	134.2
	23	0.67	21.60	20.26	137.5	135	2,335	145.9	2,405	145.7	2,885	144.2
	24	0.72	21.60	20.16	147.4	149	2,505	156.7	2,580	156.4	3,095	154.7
	25	0.78	21.60	20.04	159.2	149	2,695	168.5	2,775	168.2	3,335	166.7
	26	0.84	21.60	19.92	170.9	149	2,885	180.2	2,970	179.9	3,565	178.3

* Including bell and spigot bead. Calculated weight of pipe rounded off to nearest 5 lb.
† Average weight per foot based on calculated weight of pipe before rounding.

* Including bell and spigot bead. Calculated weight of pipe rounded off to nearest 5 lb.
† Average weight per foot based on calculated weight of pipe before rounding.

TABLE 8.2 (contd.)

STANDARD THICKNESSES, DIAMETERS AND WEIGHTS OF PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

Nom. Diam. *in.*	Thickness Class	Thickness *in.*	Outside Diam. *in.*	Inside Diam. *in.*	Weight of Barrel per Foot *lb*	Weight of Bell and Spigot Bead *lb*	Weight (*lb*) Based on					
							16-ft Laying Length		16½-ft Laying Length		20-ft Laying Length	
							Per Length*	Avg. per Foot†	Per Length*	Avg. per Foot†	Per Length*	Avg. per Foot†
20	21	0.57	22.06	20.92	120.1	137	2,060	128.7	2,120	128.4	2,540	127.0
	22	0.62	22.06	20.82	130.3	137	2,220	138.9	2,285	138.6	2,745	137.2
	23	0.67	22.06	20.72	140.5	137	2,385	149.1	2,455	148.8	2,945	147.3
	24	0.72	22.06	20.62	150.6	152	2,560	160.1	2,635	159.8	3,165	158.2
	25	0.78	22.06	20.50	162.7	152	2,755	172.2	2,835	171.9	3,405	170.3
	26	0.84	22.06	20.38	174.7	152	2,945	184.2	3,035	184.0	3,645	182.3
	27	0.91	22.06	20.24	188.7	152	3,170	198.2	3,265	198.0	3,925	196.3
	28	0.98	22.06	20.10	202.5	171	3,410	213.2	3,510	212.8	4,220	211.0
24	21	0.63	25.80	24.54	155.4	171	2,655	166.0	2,735	165.8	3,280	164.0
	22	0.68	25.80	24.44	167.4	171	2,850	178.1	2,935	177.8	3,520	176.0
	23	0.73	25.80	24.34	179.4	171	3,040	190.1	3,130	189.8	3,760	188.0
	24	0.79	25.80	24.22	193.7	191	3,290	205.6	3,385	205.3	4,065	203.2
	25	0.85	25.80	24.10	207.9	191	3,515	219.8	3,620	219.5	4,350	217.4
	26	0.92	25.80	23.96	224.4	191	3,780	236.3	3,895	236.0	4,680	234.0
	21	0.63	26.32	25.06	158.6	174	2,710	169.5	2,790	169.1	3,345	167.3
	22	0.68	26.32	24.96	170.9	174	2,910	181.8	2,995	181.4	3,590	179.6
	23	0.73	26.32	24.86	183.1	174	3,105	194.0	3,195	193.6	3,835	191.8
	24	0.79	26.32	24.74	197.7	194	3,355	209.8	3,455	209.5	4,150	207.4
	25	0.85	26.32	24.62	212.2	194	3,590	224.3	3,695	224.0	4,440	221.9
	26	0.92	26.32	24.48	229.0	194	3,860	241.1	3,970	240.7	4,775	238.7
	27	0.99	26.32	24.34	245.8	221	4,155	259.6	4,275	259.2	5,135	256.8
	28	1.07	26.32	24.18	264.8	221	4,460	278.6	4,590	278.2	5,515	275.8
30	21	0.73	32.00	30.54	223.7	254	3,835	239.6	3,945	239.1	4,730	236.4
	22	0.79	32.00	30.42	241.7	254	4,120	257.6	4,240	257.1	5,090	254.4
	23	0.85	32.00	30.30	259.5	254	4,405	275.4	4,535	274.9	5,445	272.2
	24	0.92	32.00	30.16	280.3	280	4,765	297.8	4,905	297.3	5,885	294.3
	25	0.99	32.00	30.02	300.9	280	5,095	318.4	5,245	317.9	6,300	314.9
	26	1.07	32.00	29.86	324.4	280	5,470	341.9	5,635	341.4	6,770	338.4
	27	1.16	32.00	29.68	350.7	318	5,930	370.6	6,105	370.0	7,330	366.6

* Including bell and spigot bead. Calculated weight of pipe rounded off to nearest 5 lb.
† Average weight per foot based on calculated weight of pipe before rounding.

TABLE 8.2 (contd.)

STANDARD THICKNESSES, DIAMETERS AND WEIGHTS OF PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

Nom. Diam. in.	Thickness Class	Thickness in.	Outside Diam. in.	Inside Diam. in.	Weight of Barrel per Foot lb	Weight of Bell and Spigot Bead lb	Weight (lb) Based on					
							16-ft Laying Length		16⅔-ft Laying Length		20-ft Laying Length	
							Per Length*	Avg. per Foot†	Per Length*	Avg. per Foot†	Per Length*	Avg. per Foot†
36	21	0.81	38.30	36.68	297.7	347	5,110	319.4				
	22	0.87	38.30	36.56	319.2	347	5,455	340.9				
	23	0.94	38.30	36.42	344.2	347	5,855	365.9				
	24	1.02	38.30	36.26	372.7	390	6,355	397.1				
	25	1.10	38.30	36.10	401.1	390	6,810	425.5				
	26	1.19	38.30	35.92	432.9	390	7,315	457.3				
	27	1.29	38.30	35.72	468.0	445	7,935	495.8				
	28	1.39	38.30	35.52	502.9	445	8,490	530.7				
42	21	0.90	44.50	42.70	384.6	450	6,605	412.7				
	22	0.97	44.50	42.56	413.9	450	7,070	442.0				
	23	1.05	44.50	42.40	447.2	450	7,605	475.3				
	24	1.13	44.50	42.24	480.4	510	8,195	512.3				
	25	1.22	44.50	42.06	517.6	510	8,790	549.5				
	26	1.32	44.50	41.86	558.7	510	9,450	590.6				
	27	1.43	44.50	41.64	603.7	585	10,245	640.3				
	28	1.54	44.50	41.42	648.5	585	10,960	685.1				
48	21	0.98	50.80	48.84	478.6	556	8,215	513.4				
	22	1.06	50.80	48.68	516.8	556	8,825	551.6				
	23	1.14	50.80	48.52	554.9	556	9,435	589.6				
	24	1.23	50.80	48.34	597.6	634	10,195	637.2				
	25	1.33	50.80	48.14	644.9	634	10,950	684.5				
	26	1.44	50.80	47.92	696.7	634	11,780	736.3				
	27	1.56	50.80	47.68	752.9	735	12,780	798.8				
	28	1.68	50.80	47.44	808.9	735	13,675	854.8				

* Including bell and spigot bead. Calculated weight of pipe rounded off to nearest 5 lb.
† Average weight per foot based on calculated weight of pipe before rounding.

TABLE 8.3—STANDARD THICKNESSES AND WEIGHTS OF PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

These thicknesses and weights are for pipe laid without blocks, on flat-bottom trench, with tamped backfill, under 5 ft of cover. For other conditions see Tables 8.2 and 8.4 hereof and ASA A21.1 (AWWA C101), "Manual for the Computation of Strength and Thickness of Cast Iron Pipe."

Size *in.*	Thickness *in.*	Outside Diam. *in.*	Weight (*lb*) Based on					
			16-ft Laying Length		16½-ft Laying Length		20-ft Laying Length	
			Avg. per Foot*	Per Length†	Avg. per Foot*	Per Length†	Avg. per Foot*	Per Length†
Class 50—50-psi Pressure—115-ft Head								
3	0.32	3.96	12.4	195	12.3	205		
4	0.35	4.80	16.5	265	16.4	270		
6	0.38	6.90	25.9	415	25.8	425		
8	0.41	9.05	37.0	590	36.9	610		
10	0.44	11.10	49.1	785	49.0	810		
12	0.48	13.20	63.7	1,020	63.6	1,050	63.0	1,260
14	0.48	15.30	74.6	1,195	74.5	1,230	73.7	1,475
16	0.54	17.40	95.2	1,525	95.0	1,570	94.0	1,880
18	0.54	19.50	107.6	1,720	107.4	1,770	106.2	2,125
20	0.57	21.60	125.9	2,015	125.7	2,075	124.2	2,485
24	0.63	25.80	166.0	2,655	165.8	2,735	164.0	3,280
30	0.79	32.00	257.6	4,120	257.1	4,240	254.4	5,090
36	0.87	38.30	340.9	5,455				
42	0.97	44.50	442.0	7,070				
48	1.06	50.80	551.6	8,825				
Class 100—100-psi Pressure—231-ft Head								
3	0.32	3.96	12.4	195	12.3	205		
4	0.35	4.80	16.5	265	16.4	270		
6	0.38	6.90	25.9	415	25.8	425		
8	0.41	9.05	37.0	590	36.9	610		
10	0.44	11.10	49.1	785	49.0	810		
12	0.48	13.20	63.7	1,020	63.6	1,050	63.0	1,260
14	0.51	15.30	78.8	1,260	78.7	1,300	77.8	1,555
16	0.54	17.40	95.2	1,525	95.0	1,570	94.0	1,880
18	0.58	19.50	114.8	1,835	114.6	1,890	113.3	2,265
20	0.62	21.60	135.9	2,175	135.7	2,240	134.2	2,685
24	0.68	25.80	178.1	2,850	177.8	2,935	176.0	3,520
30	0.79	32.00	257.6	4,120	257.1	4,240	254.4	5,090
36	0.87	38.30	340.9	5,455				
42	0.97	44.50	442.0	7,070				
48	1.06	50.80	551.6	8,825				
Class 150—150-psi Pressure—346-ft Head								
3	0.32	3.96	12.4	195	12.3	205		
4	0.35	4.80	16.5	265	16.4	270		
6	0.38	6.90	25.9	415	25.8	425		
8	0.41	9.05	37.0	590	36.9	610		
10	0.44	11.10	49.1	785	49.0	810		
12	0.48	13.20	63.7	1,020	63.6	1,050	63.0	1,260
14	0.51	15.65	80.7	1,290	80.5	1,330	79.7	1,595
16	0.54	17.80	97.5	1,560	97.3	1,605	96.3	1,925
18	0.58	19.92	117.2	1,875	117.0	1,930	115.8	2,315
20	0.62	22.06	138.9	2,220	138.6	2,285	137.2	2,745
24	0.73	26.32	194.0	3,105	193.6	3,195	191.8	3,835
30	0.85	32.00	275.4	4,405	274.9	4,535	272.2	5,445
36	0.94	38.30	365.9	5,855				
42	1.05	44.50	475.3	7,605				
48	1.14	50.80	589.6	9,435				

* Average weight per foot based on calculated weight of pipe before rounding.
† Including bell and spigot bead. Calculated weight of pipe rounded off to nearest 5 lb.

TABLE 8.3 (contd.)—STANDARD THICKNESSES AND WEIGHTS

Size *in.*	Thickness *in.*	Outside Diam. *in.*	Weight (*lb*) Based on					
			16-ft Laying Length		16½-ft Laying Length		20-ft Laying Length	
			Avg. per Foot*	Per Length†	Avg. per Foot*	Per Length†	Avg. per Foot*	Per Length†
Class 200—200-psi Pressure—462-ft Head								
3	0.32	3.96	12.4	195	12.3	205		
4	0.35	4.80	16.5	265	16.4	270		
6	0.38	6.90	25.9	415	25.8	425		
8	0.41	9.05	37.0	590	36.9	610		
10	0.44	11.10	49.1	785	49.0	810		
12	0.48	13.20	63.7	1,020	63.6	1,050	63.0	1,260
14	0.55	15.65	86.4	1,380	86.3	1,425	85.4	1,710
16	0.58	17.80	104.0	1,665	103.8	1,715	102.8	2,055
18	0.63	19.92	126.5	2,025	126.2	2,080	125.0	2,500
20	0.67	22.06	149.1	2,385	148.8	2,455	147.3	2,945
24	0.79	26.32	209.8	3,355	209.5	3,455	207.4	4,150
30	0.92	32.00	297.8	4,765	297.3	4,905	294.3	5,885
36	1.02	38.30	397.1	6,355				
42	1.13	44.50	512.3	8,195				
48	1.23	50.80	637.2	10,195				
Class 250—250-psi Pressure—577-ft Head								
3	0.32	3.96	12.4	195	12.3	205		
4	0.35	4.80	16.5	265	16.4	270		
6	0.38	6.90	25.9	415	25.8	425		
8	0.41	9.05	37.0	590	36.9	610		
10	0.44	11.10	49.1	785	49.0	810		
12	0.52	13.20	68.5	1,095	68.4	1,130	67.8	1,355
14	0.59	15.65	92.7	1,485	92.5	1,525	91.5	1,830
16	0.63	17.80	112.9	1,805	112.7	1,860	111.4	2,230
18	0.68	19.92	136.3	2,180	136.1	2,245	134.7	2,695
20	0.72	22.06	160.1	2,560	159.8	2,635	158.2	3,165
24	0.79	26.32	209.8	3,355	209.5	3,455	207.4	4,150
30	0.99	32.00	318.4	5,095	317.9	5,245	314.9	6,300
36	1.10	38.30	425.5	6,810				
42	1.22	44.50	549.5	8,790				
48	1.33	50.80	684.5	10,950				
Class 300—300-psi Pressure—693-ft Head								
3	0.32	3.96	12.4	195	12.3	205		
4	0.35	4.80	16.5	265	16.4	270		
6	0.38	6.90	25.9	415	25.8	425		
8	0.41	9.05	37.0	590	36.9	610		
10	0.48	11.10	53.1	850	53.0	875		
12	0.52	13.20	68.5	1,095	68.4	1,130	67.8	1,355
14	0.59	15.65	92.7	1,485	92.5	1,525	91.5	1,830
16	0.68	17.80	121.0	1,935	120.8	1,995	119.4	2,390
18	0.73	19.92	145.4	2,325	145.2	2,395	143.7	2,875
20	0.78	22.06	172.2	2,755	171.9	2,835	170.3	3,405
24	0.85	26.32	224.3	3,590	224.0	3,695	221.9	4,440
Class 350—350-psi Pressure—808-ft Head								
3	0.32	3.96	12.4	195	12.3	205		
4	0.35	4.80	16.5	265	16.4	270		
6	0.38	6.90	25.9	415	25.8	425		
8	0.41	9.05	37.0	590	36.9	610		
10	0.52	11.10	57.4	920	57.3	945		
12	0.56	13.20	73.8	1,180	73.7	1,215	73.0	1,460
14	0.64	15.65	99.8	1,595	99.7	1,645	98.7	1,975
16	0.68	17.80	121.0	1,935	120.8	1,995	119.4	2,390
18	0.79	19.92	156.2	2,500	156.1	2,575	154.6	3,090
20	0.84	22.06	184.2	2,945	184.0	3,035	182.3	3,645
24	0.92	26.32	241.1	3,860	240.7	3,970	238.7	4,775

*† See footnotes on preceding page.

TABLE 8.4

STANDARD THICKNESSES* OF PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

Laying Condition A—Flat-bottom trench, without blocks, untamped backfill
Laying Condition B—Flat-bottom trench, without blocks, tamped backfill
Laying Condition C—Pipe laid on blocks, untamped backfill
Laying Condition D—Pipe laid on blocks, tamped backfill

Size *in.*	Working Pressure *psi*	3½-ft Cover				5-ft Cover				8-ft Cover			
		Laying Condition				Laying Condition				Laying Condition			
		A	B	C	D	A	B	C	D	A	B	C	D
		Thickness—*in.*											
3	50	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.38	0.32
	100	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.38	0.32
	150	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.38	0.32
	200	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.38	0.32
	250	0.32	0.32	0.32	0.32	0.32	0.32	0.35	0.32	0.32	0.32	0.38	0.32
	300	0.32	0.32	0.32	0.32	0.32	0.32	0.35	0.32	0.32	0.32	0.38	0.32
	350	0.32	0.32	0.32	0.32	0.32	0.32	0.35	0.32	0.32	0.32	0.38	0.32
4	50	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.41	0.35
	100	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.41	0.35
	150	0.35	0.35	0.35	0.35	0.35	0.35	0.38	0.35	0.35	0.35	0.41	0.35
	200	0.35	0.35	0.35	0.35	0.35	0.35	0.38	0.35	0.35	0.35	0.44	0.35
	250	0.35	0.35	0.35	0.35	0.35	0.35	0.38	0.35	0.35	0.35	0.44	0.35
	300	0.35	0.35	0.35	0.35	0.35	0.35	0.38	0.35	0.35	0.35	0.44	0.35
	350	0.35	0.35	0.38	0.35	0.35	0.35	0.38	0.35	0.35	0.35	0.44	0.35
6	50	0.38	0.38	0.41	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.48	0.38
	100	0.38	0.38	0.41	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.48	0.38
	150	0.38	0.38	0.41	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.48	0.38
	200	0.38	0.38	0.41	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.52	0.38
	250	0.38	0.38	0.44	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.52	0.38
	300	0.38	0.38	0.44	0.38	0.38	0.38	0.44	0.38	0.38	0.38	0.52	0.38
	350	0.38	0.38	0.44	0.38	0.38	0.38	0.48	0.38	0.38	0.38	0.52	0.38
8	50	0.41	0.41	0.44	0.41	0.41	0.41	0.48	0.41	0.41	0.41	0.52	0.41
	100	0.41	0.41	0.48	0.41	0.41	0.41	0.48	0.41	0.41	0.41	0.56	0.41
	150	0.41	0.41	0.48	0.41	0.41	0.41	0.48	0.41	0.41	0.41	0.56	0.41
	200	0.41	0.41	0.48	0.41	0.41	0.41	0.52	0.41	0.41	0.41	0.56	0.44
	250	0.41	0.41	0.48	0.41	0.41	0.41	0.52	0.41	0.44	0.41	0.56	0.44
	300	0.41	0.41	0.48	0.41	0.41	0.41	0.52	0.41	0.44	0.44	0.60	0.44
	350	0.41	0.41	0.52	0.41	0.44	0.41	0.52	0.44	0.48	0.44	0.60	0.48
10	50	0.44	0.44	0.48	0.44	0.44	0.44	0.52	0.44	0.44	0.44	0.60	0.48
	100	0.44	0.44	0.52	0.44	0.44	0.44	0.52	0.44	0.48	0.44	0.60	0.48
	150	0.44	0.44	0.52	0.44	0.44	0.44	0.56	0.44	0.48	0.44	0.60	0.48
	200	0.44	0.44	0.52	0.44	0.44	0.44	0.56	0.44	0.48	0.48	0.60	0.52
	250	0.44	0.44	0.56	0.44	0.48	0.44	0.56	0.48	0.52	0.48	0.65	0.52
	300	0.48	0.44	0.56	0.48	0.48	0.48	0.56	0.48	0.52	0.52	0.65	0.56
	350	0.48	0.48	0.56	0.48	0.52	0.52	0.60	0.52	0.56	0.52	0.65	0.56
12	50	0.48	0.48	0.52	0.48	0.48	0.48	0.56	0.48	0.52	0.48	0.65	0.52
	100	0.48	0.48	0.56	0.48	0.48	0.48	0.56	0.48	0.52	0.48	0.65	0.52
	150	0.48	0.48	0.56	0.48	0.48	0.48	0.56	0.48	0.52	0.52	0.65	0.56
	200	0.48	0.48	0.56	0.48	0.48	0.48	0.60	0.52	0.56	0.52	0.65	0.56
	250	0.52	0.48	0.60	0.52	0.52	0.52	0.60	0.52	0.56	0.56	0.70	0.60
	300	0.52	0.52	0.60	0.52	0.56	0.52	0.60	0.56	0.60	0.56	0.70	0.60
	350	0.56	0.56	0.60	0.56	0.56	0.56	0.65	0.60	0.60	0.60	0.76	0.65
14	50	0.51	0.48	0.59	0.51	0.51	0.48	0.59	0.55	0.59	0.55	0.69	0.59
	100	0.51	0.48	0.59	0.55	0.55	0.51	0.64	0.55	0.59	0.55	0.69	0.64
	150	0.55	0.51	0.59	0.55	0.55	0.51	0.64	0.59	0.64	0.59	0.75	0.64
	200	0.55	0.51	0.64	0.59	0.55	0.55	0.64	0.59	0.64	0.59	0.75	0.69
	250	0.59	0.55	0.64	0.59	0.59	0.59	0.69	0.59	0.64	0.64	0.75	0.69
	300	0.59	0.59	0.69	0.59	0.64	0.59	0.69	0.64	0.69	0.64	0.81	0.69
	350	0.64	0.64	0.69	0.64	0.64	0.64	0.75	0.69	0.75	0.69	0.81	0.75

* Thicknesses include allowances for foundry practice, corrosion, and either water hammer or truck load.

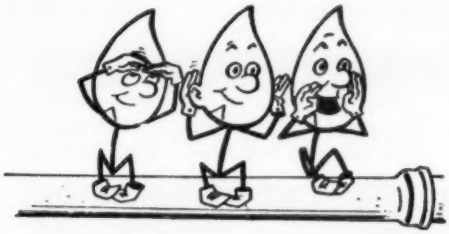
TABLE 8.4 (contd.)

STANDARD THICKNESSES* OF PIPE CENTRIFUGALLY CAST IN SAND-LINED MOLDS

Laying Condition A—Flat-bottom trench, without blocks, untamped backfill
Laying Condition B—Flat-bottom trench, without blocks, tamped backfill
Laying Condition C—Pipe laid on blocks, untamped backfill
Laying Condition D—Pipe laid on blocks, tamped backfill

Size *in.*	Working Pressure *psi*	3½-ft Cover				5-ft Cover				8-ft Cover			
		Laying Condition				Laying Condition				Laying Condition			
		A	B	C	D	A	B	C	D	A	B	C	D
		Thickness—*in.*											
16	50	0.54	0.50	0.63	0.58	0.58	0.54	0.63	0.58	0.63	0.58	0.73	0.63
	100	0.54	0.54	0.63	0.58	0.58	0.54	0.68	0.58	0.63	0.58	0.73	0.68
	150	0.58	0.54	0.63	0.58	0.58	0.54	0.68	0.63	0.68	0.63	0.79	0.68
	200	0.58	0.58	0.68	0.63	0.63	0.58	0.68	0.63	0.68	0.63	0.79	0.73
	250	0.63	0.58	0.68	0.63	0.63	0.63	0.73	0.68	0.73	0.68	0.79	0.73
	300	0.63	0.63	0.73	0.68	0.68	0.68	0.73	0.68	0.73	0.73	0.85	0.79
	350	0.68	0.68	0.73	0.68	0.73	0.68	0.79	0.73	0.79	0.73	0.85	0.79
18	50	0.58	0.54	0.63	0.58	0.58	0.54	0.68	0.63	0.68	0.63	0.79	0.68
	100	0.58	0.54	0.68	0.63	0.63	0.58	0.73	0.63	0.68	0.63	0.79	0.73
	150	0.63	0.58	0.68	0.63	0.63	0.58	0.73	0.68	0.73	0.68	0.79	0.73
	200	0.63	0.58	0.73	0.68	0.68	0.63	0.73	0.68	0.73	0.68	0.85	0.79
	250	0.68	0.63	0.73	0.68	0.68	0.68	0.79	0.73	0.79	0.73	0.85	0.79
	300	0.68	0.68	0.79	0.73	0.73	0.73	0.79	0.79	0.79	0.79	0.92	0.85
	350	0.79	0.73	0.79	0.79	0.79	0.79	0.85	0.79	0.85	0.85	0.92	0.85
20	50	0.62	0.57	0.72	0.62	0.67	0.57	0.72	0.67	0.72	0.67	0.78	0.72
	100	0.62	0.57	0.72	0.67	0.67	0.62	0.78	0.67	0.72	0.67	0.84	0.78
	150	0.67	0.62	0.72	0.67	0.67	0.62	0.78	0.72	0.78	0.72	0.84	0.78
	200	0.67	0.62	0.78	0.72	0.72	0.67	0.78	0.72	0.78	0.72	0.91	0.84
	250	0.72	0.67	0.78	0.72	0.78	0.72	0.84	0.78	0.84	0.78	0.91	0.84
	300	0.78	0.72	0.84	0.78	0.78	0.78	0.84	0.84	0.84	0.84	0.98	0.91
	350	0.84	0.78	0.84	0.84	0.84	0.84	0.91	0.84	0.91	0.84	0.98	0.91
24	50	0.68	0.63	0.79	0.68	0.73	0.63	0.79	0.73	0.79	0.73	0.85	0.79
	100	0.73	0.63	0.79	0.73	0.73	0.68	0.85	0.79	0.85	0.73	0.92	0.85
	150	0.73	0.68	0.79	0.79	0.79	0.73	0.85	0.79	0.85	0.79	0.92	0.85
	200	0.79	0.73	0.85	0.79	0.79	0.79	0.92	0.85	0.92	0.85	0.99	0.92
	250	0.79	0.79	0.85	0.85	0.85	0.79	0.92	0.85	0.92	0.85	0.99	0.99
	300	0.85	0.85	0.92	0.85	0.92	0.85	0.99	0.92	0.99	0.92	1.07	0.99
	350	0.92	0.92	0.99	0.92	0.99	0.92	0.99	0.99	1.07	0.99	1.07	1.07
30	50	0.85	0.73	0.85	0.85	0.85	0.79	0.92	0.85	0.92	0.85	0.99	0.92
	100	0.85	0.79	0.92	0.85	0.92	0.79	0.99	0.92	0.99	0.85	1.07	0.99
	150	0.92	0.79	0.92	0.92	0.92	0.85	0.99	0.92	0.99	0.92	1.07	0.99
	200	0.92	0.85	0.99	0.92	0.99	0.92	1.07	0.99	1.07	0.99	1.16	1.07
	250	0.99	0.92	1.07	0.99	1.07	0.99	1.07	1.07	1.16	1.07	1.16	1.16
36	50	0.94	0.81	1.02	0.94	1.02	0.87	1.10	0.94	1.10	0.94	1.19	1.02
	100	0.94	0.87	1.02	0.94	1.02	0.87	1.10	1.02	1.10	1.02	1.19	1.10
	150	1.02	0.87	1.10	1.02	1.10	0.94	1.10	1.02	1.19	1.02	1.19	1.19
	200	1.10	0.94	1.10	1.02	1.10	1.02	1.19	1.10	1.19	1.10	1.29	1.19
	250	1.10	1.02	1.19	1.10	1.19	1.10	1.29	1.19	1.29	1.19	1.39	1.29
42	50	1.05	0.90	1.13	1.05	1.13	0.97	1.13	1.05	1.22	1.05	1.32	1.13
	100	1.05	0.97	1.13	1.05	1.13	0.97	1.22	1.13	1.22	1.13	1.32	1.22
	150	1.13	0.97	1.22	1.13	1.22	1.05	1.22	1.13	1.32	1.13	1.32	1.32
	200	1.22	1.05	1.22	1.13	1.22	1.13	1.32	1.22	1.32	1.22	1.43	1.32
	250	1.32	1.13	1.32	1.22	1.32	1.22	1.43	1.32	1.43	1.32	1.54	1.43
48	50	1.14	0.98	1.23	1.14	1.23	1.06	1.33	1.14	1.33	1.14	1.44	1.33
	100	1.23	1.06	1.23	1.14	1.23	1.06	1.33	1.23	1.33	1.23	1.44	1.33
	150	1.23	1.14	1.33	1.23	1.33	1.14	1.44	1.33	1.44	1.33	1.56	1.44
	200	1.33	1.14	1.44	1.33	1.44	1.23	1.44	1.33	1.56	1.33	1.56	1.44
	250	1.44	1.33	1.44	1.33	1.44	1.33	1.56	1.44	1.56	1.44	1.68	1.56

* Thicknesses include allowances for foundry practice, corrosion, and either water hammer or truck load.



Percolation and Runoff

The brass really shone in New York last January 18–20, high in the upper reaches of the Park-Sheraton Hotel—AWWA brass, that is, in attendance at the annual meeting of the Board of Directors. Not only did it shine, but it managed, too, to polish off a tremendous amount of work in its 48 hours of what sometimes threatened to have to be continuous session. A resume of its admitted activities has already been presented in the January 31 letter to all members, more detailed reports will appear in next month's JOURNAL, but with more than 40 such heads together, you can bet that wasn't all!

At least some of the unreported activities were entirely reportable. There was, for instance, the time out for feast on Sunday evening, when Oregon pears, Washington king salmon, and Idaho potatoes, contributed by the Pacific-Northwest Section, made every *piece* one *de resistance*. Resisting, too, its status as has-been host, was the Florida Section, which somehow snuck in a token treat of cumquats—later labeled California oranges. And dinner done that evening, there was fruit of another Orchard to be enjoyed—even when Bill himself was officially installed as a monkey's uncle during the traditional aid-the-digestion session which he conducted. Not only fun and games, either, but riches, too, for one lucky lady at every table, for Arthur (Quarter) Beck who proved more than a match for everyone, and for the sagest of the 66 who spread their guesses from 1,654 to 2,203 in foretelling the attendance at Grand Rapids.

Back to work on Sunday night, but Monday evening was free and easy—which meant that Broadway was virtually flooded. What the legitimate theaters couldn't absorb, Radio City Music Hall did, and with more than ordinary obsequiousness—staging a show called "Many Waters," which could only have been planned for the occasion. Theaters, movies, sports, sightseeing, and so many other things to do that at least one director went home convinced that in New York even the pursuit of pleasure is sort of a ratrace.

Extracurriculation on the final day took the form of a special tribute to Rollo Blanchard, secretary of the New York Section for the past twenty years, on his retirement from full-time vice-presidency of the Neptune Meter Co. And, at last, when the work was over, it was the New York Section that saved the pieces by a chickenfeed and by doing them honor en masse at a luncheon that was *actually* planned for them.

All of which is intended to prove that, though brass is difficult to bend, it does unbend easily.

(Continued on page 34 P&R)

(Continued from page 33 P&R)

Willing Water rides again—this time astride all AWWA mail. As a matter of fact it was primarily to provide Willie still another saddle that the Association switched from stamp licking to metering its postage at the end of last year. Pictured here is Willie's first ride, just as he makes it, letter by

letter, to tell the world about Grand Rapids. With the thought that you, too, may want to tell the world, the Association has worked out a program for making plates for postal meters and electrotypes for other advertising available to any member who wants them. Details were announced in the February issue of *Willing Water*.

"Just Add Water," too, in other fields than food. Latest use of the expression was in an advertisement for Sakrete, a premixed concrete or mortar sold in the bag. With the human body more than 70 per cent water it certainly won't be long before someone works that out. As a matter of fact, we've already placed our order for two typists and a stenographer.

A new gold brick seems to have been offered to a number of AWWA members in this vicinity as a variation on the old Spanish prisoner of war swindle. This one is a Mexican bankrupt with $450,000 in U.S. funds secreted in a trunk now in the hands of U.S. customs. All you have to do to get one-third of "said sum" is . . . (but we've been begged "to treat this matter with the utmost reserve and discretion"). Suffice it to say that your $150,000 will cost you a few paltry pennies, but that comes later in the game. Meanwhile, so that none of you get our one-third share we'll not reveal the unrevealed name of the 45 per cent pure millionaire bankrupt, addressed "F."

Chemistry, which, in the words of one of its premier practitioners, provides "better things for better living," has now apparently turned its attention to better living things—football players, no less. Perhaps it was more envy than anything else that caused our snort at the "All-Chemical All-American Football Team" pictorially presented in the December 8 issue of *Chemical and Engineering News*. After all we might have trouble even finding enough water works majors to choose up sides for tiddlywinks, much less water polo. Which leads us to wonder if that isn't our fault more than theirs. What price water courses?

Steel steals the production headlines—and with the big new Fairless plant coming in, it's bound to be even more so in the future. But we who have our drops in another bucket see right through steel into what really makes the headlines. Consider, for instance, what went into the record 105,000,000-ton production of steel in 1951:

130,000,000	tons of iron ore
100,000,000	tons of coal
68,000,000	tons of coke
36,000,000	tons of limestone
58,000,000	tons of scrap
2,500,000,000	gal of fuel oil
284,000,000	gal of tar and pitch
207,000,000,000	cu ft of natural gas
27,611,000,000	kwh of electric power
6,300,000,000,000	gal of water

Even on a tonnage basis that gives water a weight advantage of 250 to 1. And that's not even heavy water.

(Continued on page 36 P&R)

Let us help you check

Your Tastes and Odors

Water works officials are invited to write to our nearest office for complete information regarding the Threshold Odor method of controlling tastes and odors.

The Threshold Odor Test supplies a relatively simple means of measuring odor intensities in water. With this test it is possible to determine the quantity of Aqua Nuchar Activated Carbon which will be most effective for removing unwanted tastes and odors from any individual water supply.

Threshold Odor Experts from our Technical Service Department are available to study your taste and odor problems without cost or obligation.

industrial
CHEMICAL SALES
division west virginia pulp and paper company

New York Central Building
230 Park Avenue
New York 17, N. Y.

Pure Oil Bldg.
35 E. Wacker Drive
Chicago 1, Illinois

Lincoln-Liberty Bldg.
Broad & Chestnut Sts.
Philadelphia 7, Pa.

2775 Moreland Blvd.
At Shaker Square
Cleveland 20, Ohio

(Continued from page 34 P&R)

Engineers interested in multi-state registration are advised by Frank H. Prouty, chairman of the Colorado Board of Registration, to obtain a "Certificate of Qualification" from the National Bureau of Engineering Registration. The bureau, an agency of the National Council of State Boards of Engineering Examiners, cannot itself register engineers, but its certificates are accepted by most registration boards and greatly minimize the trouble and expense of verifying references and facts. Further information may be obtained from an information pamphlet issued by the National Council of State Boards of Engineering Examiners, P.O. Drawer 1404, Columbia, S.C.

A Buffalo, N.Y., sales office at 3053 Main St., Buffalo 14, has been opened by Builders-Providence, Inc., and Omega Machine Co. The office will be listed as B-I-F Industries Buffalo.

Henry C. Marks, director of chemical research for Wallace & Tiernan Co., Inc., has been elected chairman of the American Chemical Society's Div. of Water, Sewage, and Sanitation Chemistry. Other officers chosen are Thurston E. Larson, head of the Illinois State Water Survey's Chemistry Subdivision, as vice-chairman; John T. Cross, principal filtration chemist at Chicago's South Dist. Filtration Plant, as secretary; and Frederick K. Lindsay, assistant manager of the National Aluminate Corporation's Zeolite Dept., as treasurer.

Clyde R. Harvill, sanitary engineer for the Houston, Tex., Water Div., has been appointed superintendent of the San Jacinto water system, in which capacity he will operate the filter plant now under construction. He had served the city of Houston for the past 23 years. For a while last year he was on loan to the Water & Sewage Div. of the National Production Authority.

M. O. Peirce, of the operating staff of New York Water Service Corp., has joined the Universal Concrete Pipe Co., with headquarters at Columbus, Ohio.

Chlorine production expansion called for by the National Production Authority has been attained—by a 55 per cent increase in 1952—along with 40 of 56 other chemical expansion goals. Still unmet is the activated carbon goal, despite a 30 per cent increase in capacity in the past year; but well over the top is soda ash, with nearly 500,000 more tons of producing capacity than water works and other industry are calling for.

W. Bedford Brown, vice-president of Well Machinery & Supply Co., died on December 25 in Fort Worth, Tex., at the age of 59. He had been in ill health for the past five years.

(Continued on page 38 P&R)

GRAVER *gives you*

ZEOLITE WATER SOFTENERS

with a choice of

4

DIFFERENT CONTROLS

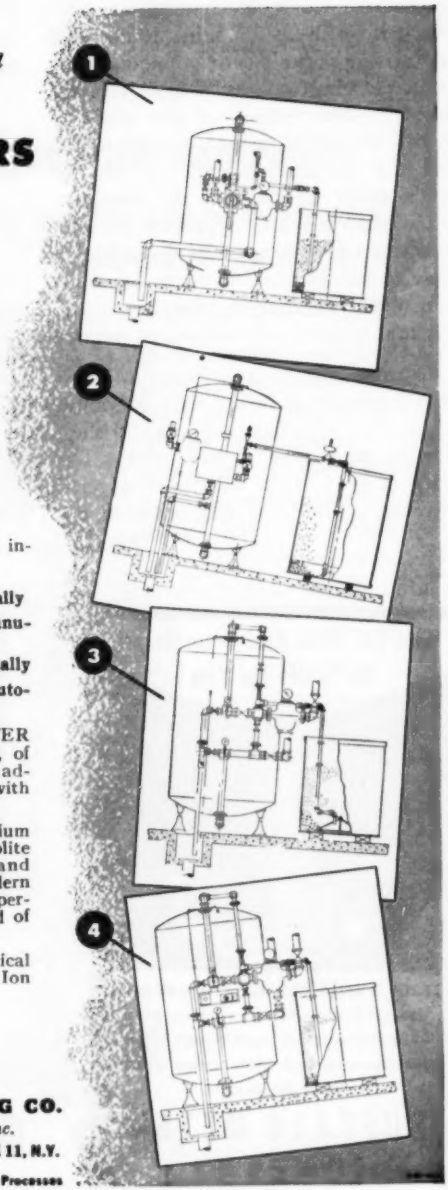
GRAVER zeolite water softener designs include 4 types of controls:

1. **Multiport disc valve, operated manually**
2. **Multiport poppet valve, operated manually and automatically.**
3. **Standard gate valves, operated manually**
4. **Individual diaphragm valves, with automatic and manual pilot control**

All components of each type of GRAVER control are *standard available equipment*, of proven operating dependability, ease of adjustment and low maintenance cost, and with readily obtainable replacement parts.

GRAVER Zeolite equipment includes sodium and hydrogen zeolite softeners, hot zeolite after-treatment, and demineralizers; and GRAVER Zeolites include all the modern highly effective synthetic resins of proven performance, checked by experts in the field of ion exchange.

Write for your free copy of the technical paper "Present Practices in the Use of Ion Exchangers."



GRAVER

GRAVER WATER CONDITIONING CO.

Division of Graver Tank & Mfg. Co., Inc.

DEPT. AWW-Z, 216 WEST 14th STREET, NEW YORK 11, N.Y.

Manufacturers of Equipment for ALL Water Conditioning Processes

(Continued from page 36 P&R)

Hep, as far as we're concerned, is the present word for General Electric, which is busily at work in the national advertising pages of our popular magazines talking about "our terrible thirst." The extent of the national thirst, the problems of quenching it, and the accomplishments of the nation's water utilities are the theme of GE's education and appreciation. All of which ought to give us enough of a glow to kindle some local implementation of the campaign. Get hep yourself and make your customers heppy!

A proposition with teeth in it is the advertisement by the clerk of Mount Dora, Fla., offering two-year-old fluoridation equipment at half price. The story is gory, with overtones of civil warring. Not trial and error at all, though perhaps trial by error. Certainly with the demand elsewhere, this ought to be classicized as "cheap at half the price."

Stark rationalization it must have been that led the "poet," C. Stark, to pen these infamous lines:

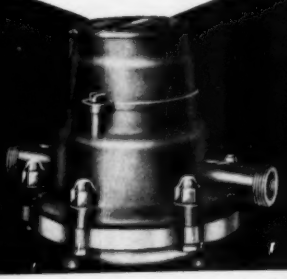
Wine to the poet is like a winged steed;
He who drinks water gains but little speed.

Surely he was riding for a fall.

Curnonsky rationalization it certainly was that led the 80-year-old prince, known as dean of French gourmets, to say of drinking water: "I've an iron constitution and I've no intention of letting it get rusty at my age." He didn't realize that "cast-iron pipes serve for centuries."

(Continued on page 40 P&R)

SIMPLICITY of American Meters PAYS OFF for You!



Buffalo AMERICAN Meters are simply designed, with fewer working parts — save money for you through lower maintenance and replacement costs. Write for details.

BUFFALO METER COMPANY
2914 Main Street
Buffalo 14, New York

TRANSITE FILTER BOTTOMS
CUT YOUR FILTRATION COSTS

Check THESE FEATURES:

- consistently-uniform backwash
- long-lasting materials
- economic installation
- strong, stable support

OFFERS SUPERIOR FILTER PLANT PERFORMANCE AT LESS COST

Write for More Information

FILTRATION EQUIPMENT CORPORATION
P. O. BOX 1331 • ROCHESTER 3, N. Y.

MUELLER

INSERTING VALVES AND EQUIPMENT

for inserting control valves where a shutdown is impractical

H-800 INSERTING VALVE

New smaller valve sleeve permits fast, easy installation in minimum space. Valve mechanism is the same as standard Mueller gate valve (repair parts interchangeable). Sizes 4", 6", and 8" (sizes of valves correspond to size of main).

H-810 BASIC INSERTING EQUIPMENT

An assembly of pressure confining units plus a slide valve. Permits the drilling of the main and inserting of the valve plug easily and safely, with no water loss.

DRILLING MACHINE

The C-C hand-operated or C-1 power-operated machine may be used for both drilling the main and inserting the valve plug. The C-1 machine may be operated either by the H-660 Air Motor or the new H-602 Gasoline Engine Drive Unit.

Write for Catalog H-20 and H-602. Complete illustrated instruction manuals and parts list shipped with equipment.

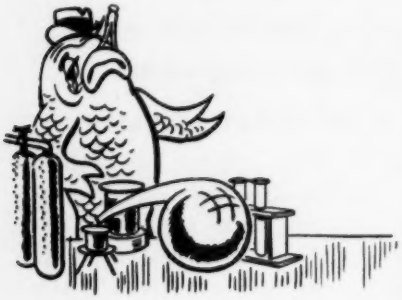
MUELLER CO.

Dependable Since 1857

MAIN OFFICE & FACTORY DECATUR, ILLINOIS

(*Continued from page 38 P&R*)

Sad Shad is the character selected by the Middlesex County, N.J., Sewerage Authority to tell the tragic tale of a polluted Raritan River system and what it means in terms of health, industry, recreation, and property values. It is Sad Shad with a clothespin on his nose, too, who gives the answers



—28 pages of them—that point to a $30,000,000 trunk sewer and sewage treatment plant that would more than take the place of the 44-plus plants required to do the job on an individual community and industry basis. It's a real selling job that the authority does in the booklet, and what makes it so much sellier than the same facts in any other form is the personality of Sad Shad. So far as cartoons are concerned these days, nothing—not even sewage works—is sacred, and everything is thereby readabler and believabler. All of which prompts us to remind you: if you have something to sell, just add Willing Water!

Speaking of characters, though, Myrtle the Turtle might well qualify as precursor to the current crop, limited though she was by being alive. Myrtle it certainly was who made one of the telling, if not decisive, moves in convincing Midland, Mich., that it should abandon its Tittabawasse River supply in favor of a joint Lake Michigan system with Saginaw. Just like a woman, too, she did it so you wouldn't notice it—in the riverside wet well from which the city pumped its supply. "Inexplicable" was what the authorities called Myrtle's activities, for their only manifestation was the chronic waterlessness of the pump suction despite a wet wet well, a clean screen, and perfect pumps—a waterlessness, too, that could be cured merely by a momentary stopping of the pumps. It wasn't until all reasonable possibilities had been exhausted that someone thought to see for himself and caught Myrtle in the act—all of her 18 in. diam. tight against the pump intake until the pumps were stopped to release her. Precursor or not, we can definitely report her a predecessor.

(*Continued on page 42 P&R*)

Filter Sand and Gravel

Well Washed and Carefully Graded to Any Specification.
Prompt Shipment in Bulk or in Bags of 100 lb. Each.

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(Continued from page 40 P&R)

Ava Gardner as a reminder of the past may require some stretch of the imagination, but, actually, we're only thinking of her stomach. It was that that came to grief in the back country of Kenya colony, East Africa, when Ava imbibed some of the local water. With water quality up to its present snuff in our own part of the world, our people don't seem well enough aware of the ancient dangers of drinking. Nothing old-fashioned though about the treatment of Ava's maladied midriff, which was flown from Kenya to London for hospitalization and a series of 42 antibiotic injections. Oh yes, Ava went along for the ride.

Roswell M. Roper, engineer and general manager of the East Orange, N.J., Board of Water Comrs., has retired after 44 years of service to his community water supply, 35 of them in the capacity of engineer. A past chairman of the New Jersey section, he received its Fuller Award in 1949.

A new Texas office has been opened by Belco Industrial Equipment Div. with Joseph Stoy, project engineer for the past three years, as branch manager. The office will be located at 2009 Fannin St., Houston. Other changes announced by the firm include the appointment of Hapgood Kipp as district manager for the Belco Philadelphia office, the appointment of Vincent R. Cioffi as sales manager of the firm at Paterson, N.J., headquarters, and the opening of a branch office at 4418 Vineland Ave., North Hollywood, Calif., with Martin J. Sherry in charge.

(Continued on page 44 P&R)

KUPFERLE
On their reputation for performance, Kupferle Fire Hydrants deserve consideration for any installation.
Full lines for public and private installations.
Send for Specification sheets.
JOHN C. KUPFERLE FOUNDRY CO.
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are specified by water works engineers

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4. Lengthen Filter Runs.
5. Higher Rates of Filtration.
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Write today for Bulletin 451 and a list of water purification plants that have gone modern.

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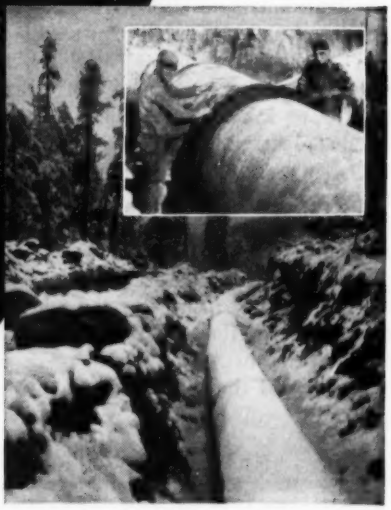
516 N. CHARLES ST. BALTIMORE

DENVER, COLO.—At 9,400 ft. elevation and 10° temperature, construction of Denver's new 54" Ranch Creek line went forward with steel pipe joined by Dresser Couplings. The line carries water to the Moffat Tunnel to help provide for Denver's rapid growth.

A DRESSER-COUPLED STEEL LINE delivers water cheaper



No matter if your problem is terrain . . . weather . . . labor . . . or time . . . the cheapest way to deliver water to the place where it turns into revenue is with a Dresser-Coupled steel line. It's the experienced engineer's way to get a superior line and still reduce *installation* and maintenance costs . . .

Once you have discovered the ease of construction of such a line, you'll know why more and more engineers specify them every year. Long, strong sections of steel pipe are easily put in place and quickly joined with factory-made, virtually foolproof Dresser Couplings. Construction proceeds rapidly even over rugged terrain like that shown here.

Leakage losses are eliminated. *Controlled gasket pressure*, provided by the bolting-up process in a Dresser Coupling, is your assurance of the correct *sealing* pressure all around the joint. Resilient Dresser gaskets absorb stresses from vibration, contraction and expansion, yet keep the joint "flexible-tight".

Maintenance is cut to the bone, too. Dresser Couplings last for life, and the absence of heat in joining prevents damage to glass-smooth pipe linings. High carrying capacity is sustained.

Experience all over the world proves that a Dresser-Coupled steel line gives you the ultimate in performance and economy. See your Dresser Sales Engineer or write our Bradford Office for literature.

Be Sure you, too, get the best line at the best price. Put steel pipe and Dresser Couplings in your specifications.

DRESSER

"FLEXIBLE-TIGHT"

COUPLINGS

Dresser Manufacturing Division, 59 Fisher Ave., Bradford, Pa. (One of the Dresser Industries). Warehouses: 1121 Rothwell St., Houston, Texas; 101 S. Bayshore Highway, South San Francisco, California. Sales Offices: New York, Philadelphia, Chicago, Houston, South San Francisco. In Canada: 629 Adelaide St., W., Toronto, Ont.

(Continued from page 42 P&R)

Calling all vest pockets is the newest thing in radio communication—a radio paging service using really vest-pocket size receivers capable of picking up messages within a 25-mile radius of the transmitting station. Actual dimensions of one of these "better mousetraps," or "walkie-hearies," are 5 x 2 x $\frac{3}{8}$-in., about the same as a king-size cigarette pack, but containing three tiny tubes, receiving and relaying equipment, a push-button tuner, and a 4-in. plastic aerial. Companies subscribing to the service, at $12 to $20 per month per receiver, phone their calls to a central office; the calls are then transmitted repeatedly using the name or a code number of the person called, the receiver calls his own office for instructions, and the office informs central that the call has been received.

For the moment, the service is available only in the larger cities, but it is spreading rapidly as doctors, sales organizations, and service groups begin to find it saves time, trouble, and money in their work. New York's Aircall, Inc., and Cincinnati's Page-ette were the pioneers, the former in business for two successful years; but within the past two months a dozen or more other cities introduced or prepared for this peanut page. Right now the economics of small range and population density are bound to restrict the service to metropolitan areas, but in this age of atomics and transistors it shouldn't take too long to breach the 25-mile limit and fix it so that even the small-town water works man can wear his vest to work.

(Continued on page 46 P&R)

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LIGHTWEIGHT MODEL

Catalog No. 25K

On Request

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Pipe Line Equipment

New Hyde Park **New York**

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and Master of all, too!

It's the Omega Universal — the one volumetric feeder for *all* dry materials — from fine powder to coarse lumps. Simple, rugged, dependable, this feeder puts chemical feeding on a sound and economical footing. That's why there are probably more Universal Feeders in use today than any other style or make of feeder. Send for Bulletin 20-J10 and complete details. Omega Machine Company, (Division of B-I-F Industries), 365 Harris Ave., Providence 1, Rhode Island.

B-I-F INDUSTRIES

OMEGA

The Last Word in Feeders

OMEGA

(Continued from page 44 P&R)

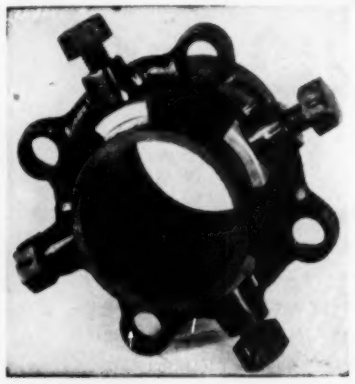
Fire water seems to be causing new problems these days, from the burnings of Adamsville, Ohio, to the burns of Scotland. What perturbs Adamsville's 175 populants is the fact that the water from their town wells can't be used near an open flame. Despite the fact that the three sets of gasoline pumps near the wells were checked and pronounced leakless, the water supply persists in igniting in the mere vicinity of a match. Meanwhile, the canny Scots are beginning to consider themselves uncanny in having agreed to export water from the burns of their highlands to Scandinavian distilleries, which have found in water the secret of real Scotch scotch. From all reports, unless the Scots ban the export soon, we'll be unable to tell the difference between Svensk and Scotch, by yumpin' yiminy!

On quite the other hand, we have noted an ad for something called "Kalak" water, a "refreshing, sparkling, alkaline water" that "buffers alcohol" and insures against "hangovers." Only cause for pause, as a matter of fact, is its uncomfortably familiar slogan: "Eat — Drink — Be Merry!" Which may suggest a permanent cure, but rather too drastic a one for our taste.

For fire or extinguishment, though, it's water H_2O!

Ross L. Dobbin, general manager of the Peterborough, Ont., Utilities Com., has been elected president of the Engineering Inst. of Canada for the 1953–54 term. He will take office in Halifax, N.S., next May.

(Continued on page 48 P&R)



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Also CI-60 charcoal cast iron bolts for mechanical joints; bell-joint Leak Clamps and Gasket Sealer Compound.

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H. Y. CARSON COMPANY
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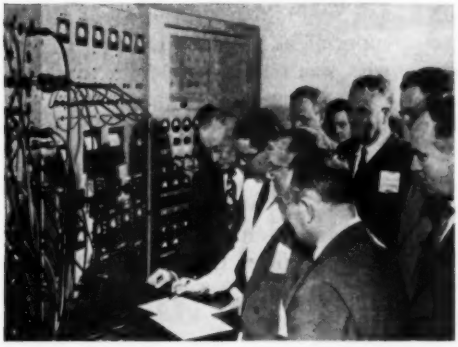
McILROY PIPELINE-NETWORK ANALYZER SAVES DAYS of CALCULATION



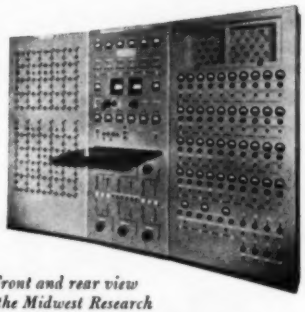
During their visit to the American Water Works Association Convention in Kansas City last April, this group of prominent hydraulic engineers and waterworks officials inspect the McIlroy Pipeline-Network Analyzer made by STANDARD ELECTRIC TIME COMPANY for the Midwest Research Institute.

Let FLUISTORS* Short Cut Your Network Calculations

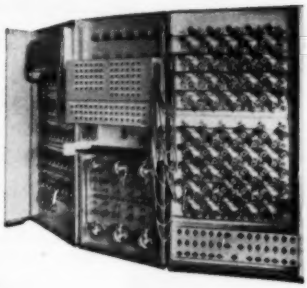
The McIlroy Pipeline-Network Analyzer performs rapid calculations of flow rates and head losses caused by fluid friction in networks of pipelines or ducts.

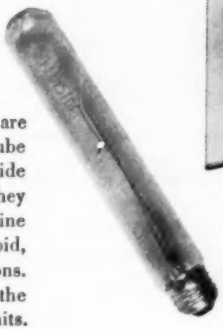
SINGLE STUDY SAVES TWICE THE COST!

Made for specific applications, the Analyzer is available for any size industrial or municipal network system; the cost varies with the design, size and other requirements. One user saved twice the cost of the Analyzer on a single study of a proposed pipeline improvement problem!



Front and rear view of the Midwest Research Institute Analyzer.





*FLUISTOR — Fluistors are specially designed non-linear tube resistors furnished in a wide range of coefficient values. They represent the various pipeline characteristics and afford a rapid, visual check of system conditions. Readings are expressed on the instruments directly in fluid units.

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THE STANDARD ELECTRIC TIME COMPANY

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(Continued from page 46 P&R)

Rainmaking, which we gave up as too respectable a cause last month, seems destined to go even that characterization one better—that is, worse. The new year had hardly gotten under way when the Weather Bureau turned about to undertake an experimental cloud seeding program in Washington state, scheduled to run from January to May and again in the fall. Dignity, yet! And if North Jersey, which in 1952 had its wettest year in history, is correct in attributing its immersion to rainmaking activities in the Far West, downright aplomb!

More than innominate—almost inexistent—was one of our Editors Anonymous (see December P&R, p. 1) when one of the huge maples lining the streets of Mt. Clemens, Mich., fell and felled Bob Hansen, local filtration superintendent, last December. Bob, who was out in a 70-mile wind snapping pictures of storm damage for a friend in the street department, was pulled out from under with "possible skull fracture and chest injuries." Fortunately for P&R, maple is a relatively soft wood and Bob was back in circulation before Christmas—circulation, filtration, and percolation.

Hammond Iron Works has acquired the Keyes Tank Co. of Provo, Utah, and the Keyes Tank & Supply Co. of Caspar, Wyo. The Keyes organizations have for the past several years been licensed to fabricate and sell Hammond storage tanks.

(Continued on page 50 P&R)

LIMITORQUE
VALVE CONTROLS

From coast to coast, hundreds of LimiTorque Controls are in service in water works and sewage disposal plants for automatic or push-button operation of valves up to 120 inch diameter. Why is acceptance so widespread? Because LimiTorque Operators are designed to provide dependable, safe and sure valve actuation at all times.

LimiTorque is self-contained and is applicable to all makes of valves. Any available power source may be used to actuate the operator: Electricity, water, air, oil, gas, etc.

A feature of LimiTorque is the torque limit switch which controls the closing thrust on the valve stem and prevents damage to valve operating parts.

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FERRIC SULPHATE

Ferri-Floc a superior coagulant offers many advantages — Here's what you can expect with Ferri-Floc.—

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SO_2

Sulphur Dioxide is effectively used in water treatment to remove objectionable odors remaining after purification.

COPPER SULPHATE will control about 90% of the micro-organisms normally encountered in water treatment plants more economically than any other chemical. Very effective for taste and odor control.

Free Literature —Send card or letter to Tennessee Corp., Grant Building, Atlanta, Georgia or Lockland, Ohio.

TENNESSEE CORPORATION

617-29 Grant Building, Atlanta, Georgia

TC
TENNESSEE CORPORATION

(Continued from page 48 P&R)

Kent S. Clow, president of James B. Clow & Sons since 1942, died at his home in Lake Forest, Ill., on December 14, 1952, at the age of 64. Except for an interval of government service during World War I, he had been with the 75-year-old firm since 1910, and had served it for ten years as its fourth president.

F. F. Osborne has joined Smith-Blair, Inc., of South San Francisco, Calif., in the capacity of general sales manager. His previous water works experience includes representing the Fairbanks Morse Co. and Byron Jackson Co.

J. P. Orr, southern branch manager for Rensselaer Valve Co. in Memphis, Tenn., died on Dec. 13, 1952, at the age of 57. He had been associated with the firm since his graduation from Purdue University's Engineering School in 1924, and had worked in Louisville, Ky., and Dallas, Tex., before coming to Tennessee.

Howard S. Morse, who until his retirement in 1949 was general manager and executive vice-president of the Indianapolis Water Co., has returned to that organization at the request of its new owners to serve as president. Stock control of the utility was recently transferred from the Geist Estate to Murchison Brothers Co. of Dallas, Tex. During his "retirement," Morse had remained on the utility's Board of Directors, had presided over the Marion County council and had served as president of the Indianapolis Board of Sanitary Commissioners.

KLETT SUMMERSON
ELECTRIC PHOTOMETER

Adaptable for Use in Water Analysis

Can be used for any determination in which color or turbidity can be developed in proportion to substance to be determined

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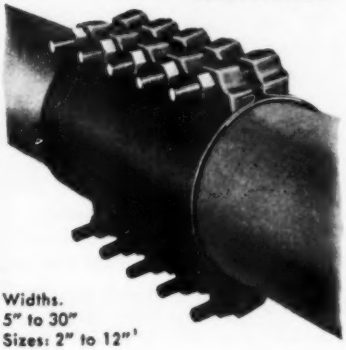
SMITH BLAIR INC.

Full Circle CLAMP COUPLINGS



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- Lowers Initial Cost
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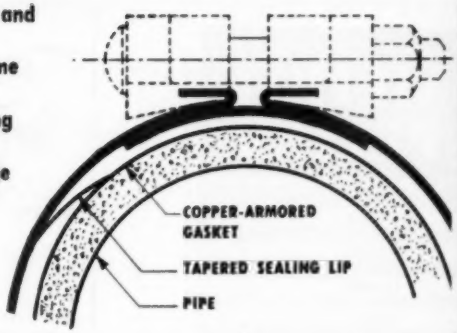

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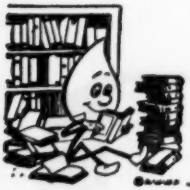

The Reading Meter

Conductimetric Analysis at Radio-Frequency. *G. G. Blake. Chemical Publishing Co., Inc., 212—5th Ave., New York, N. Y. (1952) 109 pp.; $2.75*

This is the first American edition of a British text on an electronic titration technique. The apparatus is described and various applications—including those involving the analysis of water—are discussed. An inversion of the process is also described, and is designed to permit the rapid, accurate matching of the concentration of a standard solution without use of a chemical balance.

Water Resources of the St. Louis Area, Missouri and Illinois. *J. K. Searcy, R. C. Baker & W. H. Durum. Circular 216, Geological Survey, Washington 25, D.C. (1952) 55 pp.; paper-bound; free*

Information on the characteristics of the available supplies in this water-rich area includes chemical analyses, turbidity records, climatological data, stream flow gagings and flood frequency statistics, and water temperature and quality data. Also furnished are data on water demands, the geology of the area, and a survey of relevant law and legislation.

(*Continued on page 54*)

MUNICIPAL SUPPLIES

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WATERWORKS
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- It maintains high hydraulic efficiency indefinitely. Concrete pipe does not tuberculate.
- It minimizes taste, odor and dirty water difficulties.
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PORTLAND CEMENT ASSOCIATION
33 W. Grand Ave. / Chicago 10, Ill.
A national organization to improve and extend the uses of portland cement and concrete through scientific research and engineering field work

The Reading Meter

(Continued from page 52)

Lead Work for Modern Plumbing. *David M. Borcina, ed. Lead Industries Assn., 420 Lexington Ave., New York 17, N.Y. (1952) 164 pp.; plastic ring binding; $1.50*

This handbook-sized text includes an illustrated section on the jointing of cast-iron pipe, and instructions for bending lead water pipe, wiping lead joints, and the use of calking and other tools, as well as much material intended primarily for the plumber. Explanations are brief but explicit, and helpful illustrations are profusely used.

Ground-Water Levels in Ohio, 1949–1950. *Paul Kaser. Bul. 25, Div. of Water, State Dept. of Natural Resources, Columbus, Ohio (1952) 103 pp.; paperbound; free*

Prepared in cooperation with the Water Resources Div. of the U.S. Geological Survey, this bulletin summarizes the observation-well and other pertinent data collected in Ohio during a two-year period. Most noteworthy among the trends observed were a gradual decline during 1949 and a sharp rise in early 1950. A summary of stream flow and meteorological data fills out the background of the report.

Methods of Financing Sewers and Sewage Treatment Works in West Virginia. *Pub. 8, Bureau for Government Research, West Virginia Univ. State Dept. of Health & State Water Com., Charleston, W.Va. (1952) 72 pp.; paperbound; free*

This survey of municipal practice includes a brief review of the pollutional problem in West Virginia, the financial, political, and organizational machinery required, and a summary of financing methods available. A report on the status of sewage treatment projects and existing plant is included.

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Sodium Fluoride—97%
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The CLARIFLOW gives control over each individual function of controlled reaction stage flocculation, vertical clarification and positive slurry thickening, and removal.

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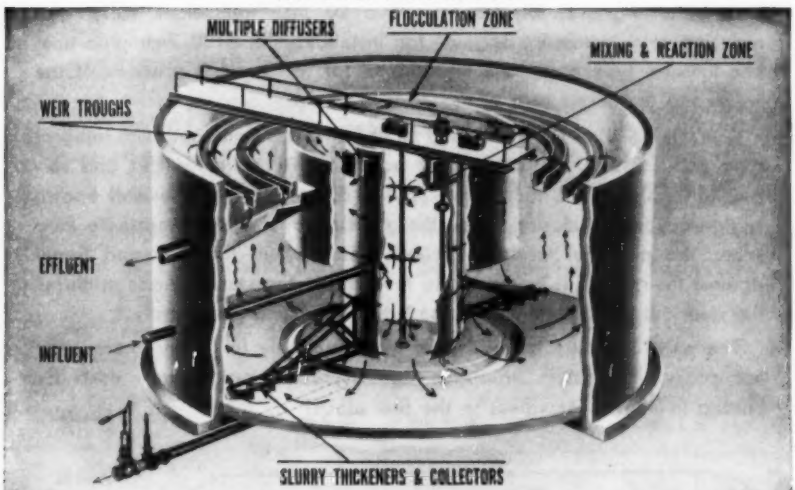

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Key: In the reference to the publication in which the abstracted article appears, **39**:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, **39**:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH—Bulletin of Hygiene (Great Britain); CA—Chemical Abstracts; Corr.—Corrosion; IM—Institute of Metals (Great Britain); PHEA—Public Health Engineering Abstracts; SIW—Sewage and Industrial Wastes; WPA—Water Pollution Abstracts (Great Britain).*

AQUATIC ORGANISMS

Development of Green Algae and Other Organisms in Plastic Water Pipes. A. VAN DER WERFF. Water (Neth.), **36**:84 (Mar. 27, '52). A partly transparent, orange-colored polysanite pipe 12 mm in diam., previously cleaned and disinfected, was filled with tap water, seeded with *Chlorella* (green alga), and placed in light. Green strip developed in approx. 6 days; spore formation took place in 12 days to such extent that water was green; musty taste noted. After approx. 6 weeks jelly-like layer of bacteria, with many green and blue algae, flagellates, and amebas, were present. Repetition of expts. showed same results. Seeding clean pipe with *Chlamydomonas* species showed green algae. Comparative results with galvanized copper tubes in dark and light showed masses of green algae and diatoms in plastic pipes and some colorless, flocculent material with some bacteria and few algae in copper pipe. Growth is greatest during spring and early summer. Some algae, kept for weeks in darkness, even in galvanized copper pipes, will develop in any plastic pipe, which allows some light to diffuse.—*W. Rudolfs*

Some Observations on the Correlation of Chemical and Biological Sequences at the Water Works at Leeds. E. A. SPAUL. J. Inst. Wtr. Engrs. (Br.), **6**:277 ('52). Leeds obtains water from catchment areas on eastern slopes of Pennines. Water from Leighton Res. passes through liming plant to increase pH, then by pipe to Kellesing, on by tunnel to Swinsty Res. and then through pipe to Eccup Res. Samples for biological examn. are taken monthly, weekly, or semiweekly according to their importance in relation to information needed and their accessibility. Water has avg. pH of 6.5; elec. cond., 150–110; albuminoid NH_3, 0.45–0.025; total solids, 140–90; and chlorides, 16–12. All showed downward trend during 3 yr, while color (90–20) and oxygen absorbed from $KMnO_4$ (5.5–1.5) were seasonally high in winter and low in summer. No appreciable amount of plankton above Eccup, but some species assumed significant growth in Eccup Res. In latter part of '50 and '51 there was increased growth, particularly of *Asterionella*, which blocked filter beds. Of other diatoms found, only *Rhizoselina* and *Tabellaria* need be mentioned. Former had periods of growth during spring and autumn of '49 and '50. *Tabellaria fenestrata* var. *asterionelloides* was present to some extent during spring and autumn of '49 and from Sept. '50 to June '51. *Anabaena* developed considerably between July and Oct. '49. Spinksburn Beck and conduits around Eccup, both of which receive drainage from agricultural land, have chem. content with high total solids, albuminoid ammonia, and hardness, and also high production. Former makes relatively high contribution to fertility of system, and productivity is such that periodic cleansing is necessary. Extent to which thermal stratification and bottom deposits in deep reservoirs of this long-established system can affect chemical content and contribute to biological growth is unknown and requires separate investigation. Measures to reduce fertility, instituted about '47, included removal of decaying vegetation from shallow marginal water; clearing, deepening and widening inlets; cropping of vegtation in these areas; and treatment of stone pitching to remove and control weeds, etc. Bacteriological records show no evidence of serious pollution, and such as does exist can be dealt with effectively by filtration. Point of interest is, however, approx. coincidence of high numbers at Eccup with presence of birds, especially gulls, during autumn and winter. Lab. expts. demonstrated lethal effect of ultrasonic waves and attention was directed to their use for control of aquatic organisms. Fish, tadpoles, water fleas, pro-

(*Continued on page 64*)

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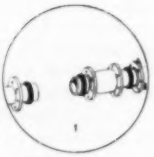

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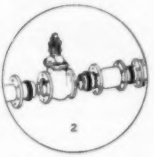

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WATERFORD, NEW YORK

(*Continued from page 62*)

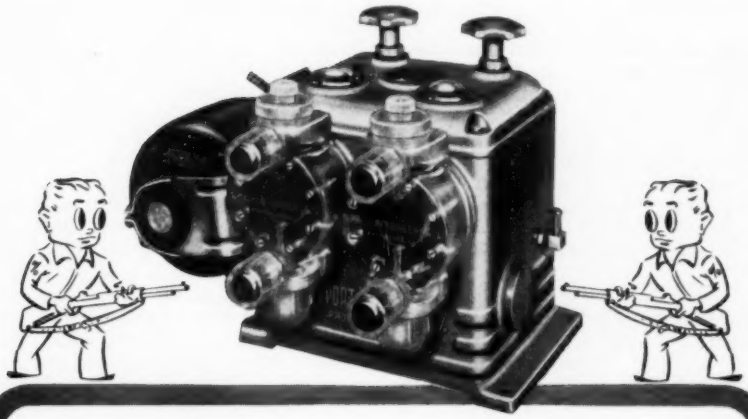
tozoa, and algae confined to 14″ column of water above crystal were exposed to varying ultrasonic power for different time intervals and lethal doses determined.—*H. E. Babbitt*

The Infestation of Water Works by *Dreissensia polymorpha*, a Fresh-Water Mussel. K. B. CLARK. J. Inst. Wtr. Engrs. (Br.), **6**:370 ('52). Trouble with *Dreissensia polymorpha* in British water works is rare. Presence in water main is usually revealed by discharge of shells and increase of head loss. Mussels, dark brown or black, attach themselves by up to 200 tough, elastic fibers and usually lead sessile existence. Mussels feed on submicroscopic silt of vegetable origin and have been seen to reject extremely small diatoms. They prefer clean, slowly moving water with firm bottom. Perhaps most sensational record of trouble with *Dreissensia polymorpha* in water works was that at Hamburg in 1886. Rotterdam experienced trouble in 1887. London Metropolitan Water Board in '25 and '30 experienced reduction of 36″ main to 12″. At Great Yarmouth, 20 cu yd of mussels removed from approx. 300 yd of 24″ pipe. Trouble not confined to water works but may affect any users of water. Methods of control include scraping of mains, reservoirs, and tanks. Where control is by drying out, mussels can live 14 days in air of 100% humidity. In open air mussels die within 7 days and come away easily from pipe. If drying-out method is adopted, there should be adequate ventilation of pipe. Continuous dosing with 50 ppm of chlorine flowing slowly through main for upwards of two weeks has shown itself to be reliable method of removal. It seems that closing down main for long periods can kill only some of mussels, dead ones being held in place by neighbors and their bodies giving rise to serious taste troubles. There is ample evidence that larvae are held back by filtration but they do seem able to develop in filtered water. Prechlorination by Metropolitan Water Board and at Great Yarmouth has apparently prevented pipes downstream from becoming reinfested from river. Dose was such as to leave no residual at downstream end, usually 1.5–2 ppm.—*H. E. Babbitt*

The Heterocyst: A Botanical Enigma. F. E. FRITSCH. J. Inst. Wtr. Engrs. (Br.), **6**:74 ('52). At some stage in life cycle of some blue-green algae, there appear, in threads, somewhat larger cells of distinctive structure usually situated at frequent intervals along filaments. These large cells, known as heterocysts, are "botanical enigma." Heterocysts highly specialized as compared with ordinary blue-green cells, and their long-maintained connection with adjoining cells, as well as other features, suggests chemical activity and specialized metabolism. When reproductive period sets in, it may be that nature of secretion from heterocysts changes and something is formed that stimulates akinete formation, or perhaps there is merely alteration in reaction of contents of cells involved.—*H. E. Babbitt*

Studies on Chemicals With Selective Toxicity to Blue-Green Algae. G. P. FITZGERALD, G. C. GERLOFF & FOLKE SKOOG. Sew. Ind. Wastes, **24**:888 ('52). With *Microcystis aeruginosa* as test organism, approx. 300 org. compds. have been screened for toxicity to bloom-producing blue-green algae. Whereas many compds. are toxic to algae in concns. from 10 to 1 ppm, several compds. of quinone type structure are toxic in concns. of less than 1 ppm; one of these, 2,3-dichloronaphthoquinone, is lethal in concns. as low as 2 μg/l under conditions of these tests. This compd. known to be effective fungicide, seems selectively toxic to bloom-producing blue-green algae and is nontoxic to most green algae and higher aquatic plants. In short-term tests, it had no toxic effect on fish and other aquatic organisms, even when chemical supplied in excess of saturation level (100 μg/l). However, more detailed studies must be carried out in order to be certain 2,3-dichloronaphthoquinone is without injurious effect on fish and other organisms during long periods of exposure. Limited field tests in barrels, tanks, and lagoons contg. heavy growths of algae in lake water or sewage effluent indicate that low concns. of compd. (10–100 μg/l) are effective in selectively killing bloom-producing blue-green algae even when present in exceedingly large quants. However, much additional information required on methods of application, dosage, and frequency of treatment, before definite conclusions can be reached on whether practical use of 2,3-dichloronaphthoquinone would represent improvement over treatment with copper sulfate from standpoint of cost and effectiveness.—*PHEA*

(*Continued on page 66*)



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(Continued from page 64)

The Algicidal Effect of Certain Quaternary Ammonium Compounds. O. B. WILLIAMS, C. R. GRONINGER & N. F. ALBRITTON. Producers Monthly, **16**:8:14 ('52). Arquad S, Arquad C, and Arquad 2C + S were tested on cultures of algae. Approx. 15 ppm of any Arquad controlled growth of various strains of algae. In general 5 ppm of Arquad S is effective against *Oscillatoria*, which seems to be most common alga encountered. —*CA*

Illustrations of Fresh-Water Algae Toxic to Animals. W. M. INGRAM & G. W. PRESCOTT. Ohio-Tenn. Drainage Basins Office, Div. of Water Poln. Control, USPHS, Cincinnati, Ohio. 9 p ('52). Illustrations of so-called toxic fresh-water algae are presented to aid those working in water poln. control programs who may have cause to identify certain ones that have purportedly caused death or illness in animals. Illustrations represent species of algae that have been associated with livestock, poultry, fish, and wildlife deaths through direct toxic action. Illustrated species are: *Microcystis aeruginosa* Kutz, *Microcystis flos-aquae* (Wittr.) Kirch., *Aphanizomenon flos-aquae* (L.) Ralfs., *Anabaena flos-aquae* (Lyngb.) Breb., *Coelosphaerium Kuntzingianum* Naeg., *Coelosphaerium Naegelianum* Unger., *Gloeotrichia echinulata* (J. E. Smith) P. Richter, and *Nodularia spumigena* Mert.—*PHEA*

HYDROLOGY, CONSERVATION, AND IRRIGATION

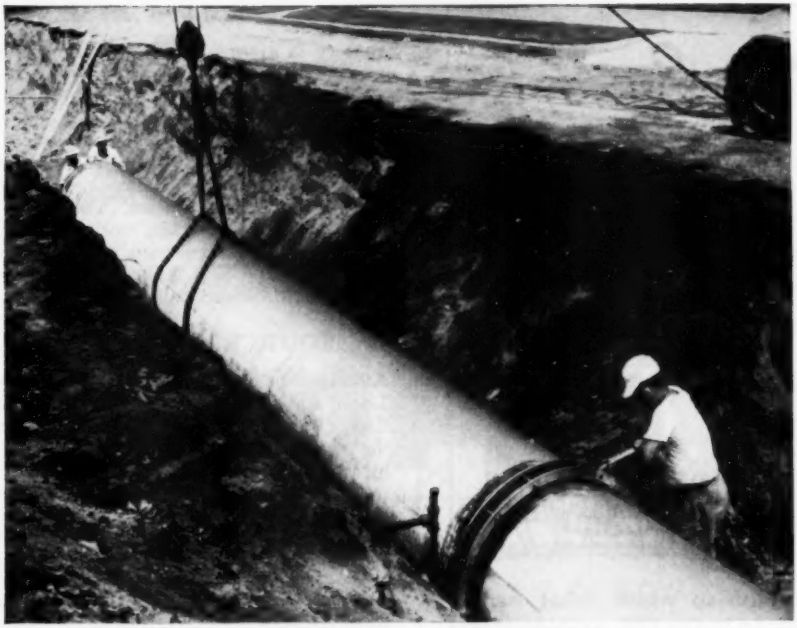
Australian Estuarine Hydrology. I. Introductory and Comparative Features. D. J. ROCHFORD. Australian J. Marine Freshwater Research, **2**:1 ('51). Methods are described of collection and anal. used in studies of the hydrology of waters and muds in estuaries in eastern and southwestern Australia. Marine, tidal, gradient, and fresh-water zones in estuarine systems are distinguished by differences in the hydrological properties of the waters—for example, the extent of the diurnal chlorinity conflict, and the chem. compn. of the bottom deposits. Particular systems are classified according to the zone which occupies the greatest vol. in the entire system. The development of conflicts of hydrological properties in tidal waters was examd. by following the diurnal range of chlorinity in several estuaries. The role of inorg. and org. phosphate in detg. productivity in estuarine waters, and the extent of chem. interactions between the waters and associated bottom deposits are discussed. These findings are applied to problems of oyster cultivation.—*CA*

Rainfall, Runoff, and Evaporation. J. GLASSPOOLE. Rep. Publ. Wks. Munic. Serv. Congr. Exhib., p. 472 ('50). Hydrological data are of importance from many aspects, including provision of water supplies, land drainage, and flood control. Studies of rainfall have shown wide variations and no marked trends have been observed which could be used for long-range forecasting. Few records of runoff are at present available, but with increasing demands for water, the detn. of runoff will be necessary. The relations between rainfall and runoff records for the Thames valley are explained. Variations in evapn. in different places and from year to year are relatively small. Evapn. may be measured by means of evapn. tanks, percolation gages, and fluctuations in levels of wells and yields of springs in the chalk. —*WPA*

Sediment Records in Midwestern United States. GUNNAR M. BRUNE. Union Géodésique et Géophysique Internationale, Assemblée Générale de Bruxelles ('51). This paper is a review of the available records of rates of sediment production in midwestern U.S. and of the need for further study of the factors affecting sediment production. A total of 192 sediment records are listed within sixteen major physiographic areas. In most of these physiographic areas there is a great scarcity of sediment records. The records are adjusted for size of drainage area, one of the most important factors influencing rates of sediment production. Other controlling factors, such as land use, rainfall and runoff, soils, topography, crop rotations, severity of channel erosion, and conservation practices, are discussed. With the possible exception of the Missouri Basin Loess Hills, much detailed research is needed to det. for each major physiographic area the important factors affecting sediment production, and the relationships involved.—*WPA*

Water Conservation in Australia. Wtr. & Wtr. Eng., **55**:203 ('51). In a report prepd. by the Australian Ministry of Development,

(Continued on page 68)



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(Continued from page 66)

an acct. is given of the major projects for water conservation in Australia. In New South Wales and Victoria there are schemes to conserve water for irrig., hydroelectric plants, and water supply and new reservoirs are to be constructed. In Queensland numerous weirs are under construction and new schemes for irrig. are being considered. In Adelaide, South Australia, work has started on a scheme for augmenting the water supply. There are also water supply schemes for Western Australia and Tasmania.—*WPA*

SOURCES OF SUPPLY

Afforestation for Water Undertakings and Local Authorities. ANON. Wtr. & Wtr. Eng. (Br.), **56**:138 (Apr. '52). Afforestation in catchment areas can be carried out by water undertakings themselves with excellent results. Alternatively suitable area could be leased to Forestry Com. If undertaken by authority itself there would be advantages of Forestry Com. Dedication Scheme, which consists of agreement in which owner undertakes to manage his woodlands for main purpose of timber production, to work to approved plan, and to employ skilled supervision. In return commission provides financial assistance to owner. Afforestation might make highly important contribution to nation's requirements. Forest is permanent asset provided that restocking after each felling of mature timber is assured.—*H. E. Babbitt*

The Relationship Between the Erosion of Soil and the Silting of Reservoirs in Cyprus. DAVID J. BURDON. J. Inst. Wtr. Engrs. (Br.), **5**:662 (Nov. '51). There is close relationship between sedimentation of reservoirs and movement of soils. Both must be considered in designing and siting reservoir. Investigations of eleven reservoirs in Cyprus have made it clear that agricultural methods, and particularly vineculture, have caused acceleration of rate of soil erosion. In Cyprus, geology and topography are closely related. There are four main topographical units: ancient, deeply dissected, lofty Troodos plateau; young, recently uplifted, alpine type Kyrenia Range; the Mesaoria, open plain of recent emergence and much silting; and coastal plains of little importance in this investigation. Cyprus has an intense Mediterranean, almost subcontin-

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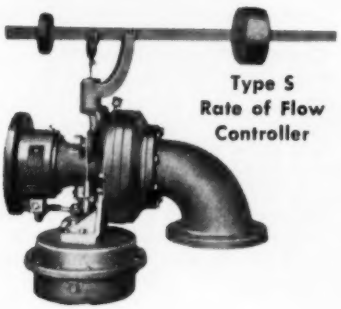

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(Continued from page 68)

ental type of climate. The summers are hot and dry from mid-June to mid-September; mean annual rainfall is from 12 in. on plains to more than 36 in. in highest parts; range of temp. is from 28° to 111°F. Relationship between soils and rates of erosion could not be studied because no soil surveys have been made. Heavy forest covers approx. 652 sq mi or 18% of island. Light forest embraces much agricultural land on which there are olive trees as well as grazing lands having scattered pines. Bare and agricultural lands embrace most of Mesaoria and almost all land devoted to cereal growing. Vineyards cover approx. 110 sq mi and are found mostly on chalk or volcanic hills. Overgrazing by flocks of sheep and goats is general; forest grazing is now effectively prohibited. Routine inspections made it clear that seven reservoirs around the Troodos plateau were silting up rapidly and that new desilting devices would have to be fitted. Measurements made in autumn of '49 stressed urgency of such measures. Tabulated data show annual percentages of losses of capacity among seven reservoirs to vary from 0.8% up to 14.33%. Erosion, in cubic feet per square mile of drainage area, has varied between 2,516 and 59,550. Brown classifies methods of controlling sedimentation in impounding reservoirs into six groups: [1] selection of reservoir site; [2] design of reservoir; [3] control of sediment flow; [4] control of sediment deposition; [5] removal of sediment deposits; and [6] watershed erosion control. Groups 1 and 2 disregard possibilities of changing rate of sediment output from drainage area. Groups 3, 4, and 5 accept fixed rate of sediment production from drainage area, as well as fixed size for reservoir, but attempt by various means to prevent all or part of sediment from forming permanent deposit in reservoir. Sixth group attempts, through control measures in watershed, to reduce quantity of sediment that will reach reservoir.—*H. E. Babbitt*

Chemical Composition of Ground Waters in Irrigated Regions. S. V. Zonn. Trudy Lab. Gidrogeol. (U.S.S.R.), 1:112 ('48). Chemical studies in five irrig. regions of the U.S.S.R. to det. the influence of season, soil, and evapn. on the compn. of ground waters. The compn. (in milliequivalents per liter) detd. for irrig. water, ground water in an irrig. plain, and ground water in a nonirrig. plain, was, resp., HCO_3^- 3.10 and 12.50; Cl^- 1.20, 82.30, and 452.30; SO_4^{--} 1.40, 44.60, and 166.30; Ca^{++} 2.80, 42.00, and 44.50; Mg^{++} 5.30, 39.70, and 201.40; Na^+ 48.30 and 382.20. The dry residue in grams per liter was 0.53, 9.19, and 40.72, resp.—*CA*

Chemical Character of Florida's Waters, 1951. A. P. Black & Eugene Brown. Fla. Board Cons., Div. Wtr. Surv. & Research, Paper No. 6 ('51). A comprehensive study is given of nearly 2,000 chem. anals. of waters. Surface waters are generally low in F, but water from the Hawthorne formation generally contains more than 1 and may contain up to 2.5 ppm F. Data on Sr content are given.—*CA*

Chemical Composition of Texas Surface Waters, 1950. Anon. Texas Board of Wtr. Engrs., 1952:1. Chemical anals. are given of hundreds of samples of waters.—*CA*

Chemical Studies of the Waters of Reelfoot Lake (Tennessee). Moris Shore. J. Tenn. Acad. Sci., 27:3 ('52). The O content of water in Reelfoot Lake decreases with depth of sampling, presence of decaying vegetation, higher content of CO_2, and lower alky. The relations of these factors to fish life are discussed. Notable variation in O was observed in the diurnal cycle with the max. shortly after sundown and the min. at daybreak.—*CA*

Ground Water Resources of Beaver County, Pennsylvania. D. W. Van Tuyl & N. H. Klein. Penn. Geol. Surv. Bul. No. W9 ('51). Analyses of waters from 26 wells are given.—*CA*

Water Resources of the Mahoning River Basin, Ohio, With Special Reference to the Youngstown Area. W. P. Cross, M. E. Schroeder, & S. E. Norris. U.S. Geol. Surv. Circ. No. 177 ('52). This study of water supply includes many chem. anals. of surface waters. At times of low water, poln. with nitrate can become a serious problem. —*CA*

Water Resources of the Detroit Area, Michigan. C. O. Wisler, G. J. Stramel, & L. B. Laird. U.S. Geol. Surv. Circ. No. 183 ('52). Analyses of surface waters and well waters are given.—*CA*

(Continued on page 72)

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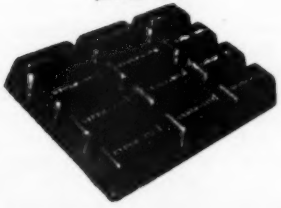

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(*Continued from page 70*)

FOREIGN WATER SUPPLIES—GENERAL

Drinking Water Supply of St. Ouen L'Aumone [Fr.]. M. VANDANGE & R. M. GRELU. L'Eau, **39**:73 (Apr. '52). St. Ouen L'Aumone (pop. 4,800) in 1951 completed new water supply system satisfying its need for 0.13 mgd (peak: 0.24 mgd), soon to be boosted to 0.185 mgd, due to industrial developments. Raw supplies, found insufficient underground, were secured from Oise R., strongly pold. by domestic and industrial wastes and necessitating very complete treatment, especially for odors due to phenols and sugar beet waste. Water system comprises treatment plant (capac. 0.63 mgd), 0.26-mil gal reservoir on 65'7" tower, and system of distr. mains. Concrete cylindrical reservoir has little overhang over tower (also concrete), which itself rests on foundation vaults connecting 5 vertical ribs reinforcing tower. Plant design, chosen by competitive bidding, includes vertical screened river intake, 2 low-pressure pumps bringing raw water and recirculated sludge in circulator unit also fed with alum solution by pump, and 2 open rapid sand filters operating in parallel. Prechlorination of raw water is practiced in spring and fall to destroy algae, and emulsion of activated carbon is fed to circulator effluent for odor reduction. Filters backwashed with filtered water and compressed air once weekly for 20–25 min. Chloramines, as Cl_2 and $(NH_4)_2SO_4$, are added to filtered water for sterilization before storage in reservoir. Results obtained with highly turbid water (white disk never visible below 6' of water in circulator) are excellent and constant. Costs reached 13,000,000 fr. for reservoir and 17,000,000 fr. for plant.—*M. Albanese*

Savings and Water Supplies [Fr.]. M. A. SAYOUR. Tech. Sanit. et Munic., **47**:47 (Mar. '52). Surveying present water supply facilities in France, author shows that 1,600,000 people in cities of from 5,000 to 10,000 and 15,000,000 in rural areas have no public water supplies; 3,000,000 of latter need private or consolidated supplies, and public works for other 12,000,000 require 2.2 bil dollars to be spent over generation. Lag in undertaking these projects is due to reduced government credits, failure of local (municipal) loans, and, particularly, lack of investment capital, a general trend in French business; whereas avg. of 73% of budget was met by invested savings in 1907–13, only 33% was invested in 1924–26, and 20% in 1952 (budget figured at pre-World War I exchange rate). Heavy taxes, reinvestment of profits, and, especially, constant depreciation of currency and government bonds are basic causes. Estd. 24 bil francs ($53,500,000 at '52 exchange rate) could be attracted by limited government bonds or obligations convertible into regular stock—twice amount normally expected.—*M. Albanese*

Water Supply of the City of Essen [Ger.]. FRANZ POTRYKUS. Gas- u. Wasserfach (Ger.), **93**:268 ('52). After a brief historical survey, the present water supply plant is described. Water is secured by bank filtration, tube wells, and by infiltration. In periods of high water only the latter two sources are used, to minimize turbidity. The water is passed through settling basins to remove suspended materials and then through filter basins, which serve for an avg. of 120 days before the upper sand layer must be removed. The bacteria count of the filtered water requires chlorination. The water is chlorinated after filtration through the Mn filters which use Magno mass, as it was found that the chlorinated water caused difficulty. The water supplied to this filter must be satd. with O before treatment. Some difficulty was encountered with setting of the Magno material, but washing with air as well as water reduced the problem. Corrosion of the mains is reduced by using a proprietary material called "Ferrosil."—*CA*

Faringdon [Gt. Br.] Rural District Regional Water Supply Scheme. K. M. HART. J. Inst. Munic. Engrs., **78**:358 ('51). Acct. given of Faringdon Rural Dist. Council water supply scheme which is nearly completed. The total pop. at present is 13,000 but allowance has been made for an increase to 18,000. The estd. daily consumption for domestic, trade, and agricultural purposes is given. There are two service reservoirs of 1 mil gal and 300,000 gal capac. Water of good quality is obtained from boreholes at Ashdown Park and Wicklesham. At Wicklesham, very fine sand is removed by coagulation with aluminum sulfate and filtration. Both water supplies are chlorinated. The

(*Continued on page 74*)

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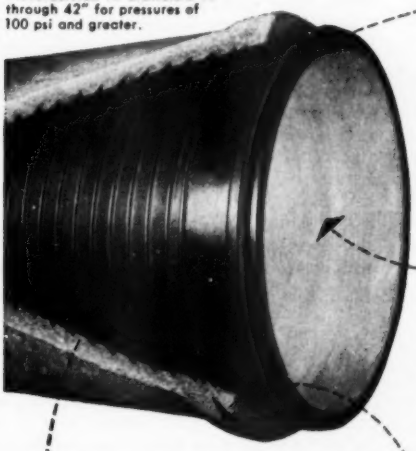

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(Continued from page 72)

supply for the works at Buscot is taken from the river Thames, and the treatment plant consists of screens, sedimentation tanks, and filters. Aluminum sulfate is used as coagulant and activated carbon is added to reduce tastes and odors. Breakpoint chlorination has been adopted and sulfur dioxide is used to dechlorinate. Costs of the scheme are given.—*WPA*

Water Supply, Cambridge, England. S. C. Bowles. W.W. Eng., **104**:564, 602 ('51). The author gives an acct. of the development of the water supply in Cambridge from 1610. The present supply comes from wells at Fulbourne and Fleam Dyke. The water is sometimes pold. by bacteria but it is of consistently good chem. quality, although it has a hardness of 250 ppm. Approx. half the supply is softened by ion exchange and the distributed water has a hardness of 130 ppm. Covered storage reservoirs are automatically controlled by the demand for water. The avg. consumption is 3.6 mgd and 110,000 people are supplied.—*WPA*

Scottish Water Supply Schemes. J. Brit. Water Works Assn., **33**:100 ('51). Schemes to increase water supplies in Scotland include the Fruid-Menzion scheme supplying Edinburgh and a regional scheme for the county of Midlothian. In the Fruid-Menzion scheme, approx. 6 mgd of water will be taken from the Fruid Water and Menzion Burn, tributaries of the Tweed. The regional scheme is designed to meet the requirements of housing developments and the Lothian coalfield. Works for treatment of the water will consist of microstrainers and slow sand filters. Other smaller schemes of the Edinburgh Corp. Water Dept. are outlined.—*WPA*

The Rossington Bridge and Butterbusk New Works of the Concaster [Gt. Br.] Corporation Water Undertaking. Anon. Wtr. & Wtr. Eng. (Br.), **56**:253 ('52). Old water works, originated in 1703, derived supply from Cheswold R. This water now being used for sanitary, fire, and other special purposes. Water for domestic and trade purposes derived from impounding reservoir at Thrybergh with capacity of 254 mil gal (Imp.) and watershed of 2,285 acres. After filtration, water conveyed by conduit 6 mi. to service reservoir at Warmsworth. Apart from temporary agreement with Sheffield Corp. for daily quantity of 133,000–200,000 gal, present avg. supply to Doncaster is (mgd): from Thrybergh, 0.55; from Langsett, 1.0; from Nutwell, 1.35; and from Thornham, 1.5. Additional bulk supply taken from Doncaster and Tickhill Joint Water Board at various points in area. Scheme for improvement was authorized in '45, including Rossington Bridge works, Finningley works, Butterbusk works, and extension of pumping mains from Nutwell and Thornham sources. Rossington Bridge and Butterbusk works were opened in '52. Former consists of two 33″-diam. boreholes, 485′ deep. Each well equipped with 10-stage Sulzer pumps, 200′ below floor level, capable of delivering 65,000 gph (Imp.) against total head of 440′. Each pump is driven by 200-hp slip-ring induction motor running at 970 rpm. Butterbusk works comprise covered reinforced concrete service reservoir with capac. of 3 mil gal (Imp.); reinforced concrete water tower with water level 92′ above top water level in adjoining reservoir, with capac. of 150,000 gal (Imp.); and 2 centrifugal pumps, each with capac. of 500 gpm (Imp.) against avg. head of 114′. Warmsworth pumping station equipped with 2 500-gpm centrifugal pumps to lift against head of 123′, moving water to Butterbusk Res. utilizing new 10″ main about 4,800′ long. New 18″ trunk main about 5,100′ long has been laid from Butterbusk Res. to borough. Thryberg supply is chlorinated to breakpoint at impounding reservoir, and Sheffield supply is chlorinated before leaving Sheffield. —*H. E. Babbitt*

The New Water Works Scheme of the Depwade [Gt. Br.] Rural District Council. Anon. Wtr. & Wtr. Eng. (Br.), **56**: 264 ('52). Comprehensive scheme incorporates distr. mains and water towers of 2 systems of water supply serving Harleston ard Long Stratton parishes. Sources here are replaced by Rushall water works but are held as standby. New 18″ borehole has been sunk into chalk at Diss to depth of 400′. Remodeled pumping plant will draw water from new and old boreholes, to pass through remodeled treatment plant, and lift water to Diss water tower and to new 145,000-gal tower to be erected near Burston Hall. 8′-diam. well has been sunk to total depth of 113′ at Rushall. Water is lifted from

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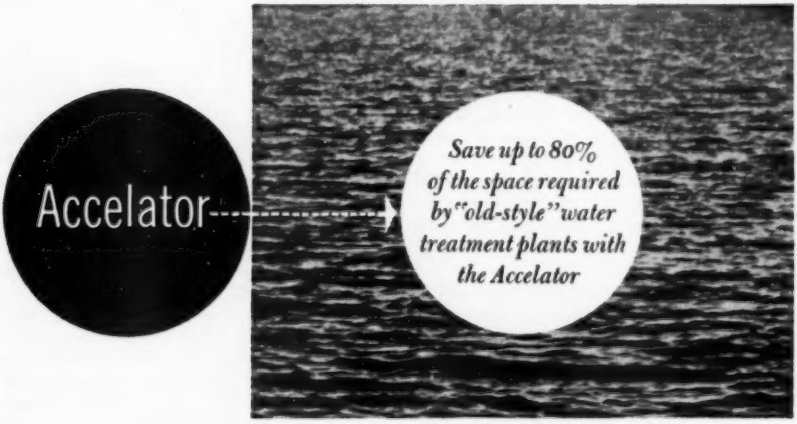
RUNNING OUT OF GROUND?



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(Continued from page 74)

here into 250,000-gal water tower at Pulham. For purposes of distr., rural dist. has been divided into 5 zones, with anticipated demand of 0.5 mgd.—*H. E. Babbitt*

Ludham Borehole: A Gravel Pack Well in The Norwich Crag [Gt. Br.]. C. L. FORBES. J. Inst. Wtr. Engrs. (Br.), **6**:362 ('52). It was decided to drill well near Ludham Airfield to yield 24,000 gph from base of Norwich Crag. Samples taken from pilot bore were submitted to sieve analysis to determine grain size distribution in aquifer. Because of nature of aquifer and pumping test on pilot bore, it was decided to use gravel pack consisting of 4" layer of well-rounded $\frac{3}{8}$"–$\frac{1}{4}$" Bridport gravel. During course of development, samples were taken to determine nature and rate of extraction of sediment from well. Peak rate of sediment production was reached 2–3 min after starting pumps, and this fell away to low value, slowly at commencement of development, but rapidly in later stages. Most sediment could be extracted by repeated stopping and restarting of pumps. Records of drawdown and pumping rates show that, for given pumping rate, drawdown decreased appreciably during course of development, indicating that extraction of finer sediment from aquifer was having desired effect. It was concluded that rate of sedimentation production was zero approx. 15 min after commencement of pumping at 24,000 gph. It was evident that safe continuous rate of pumping gives adequate margin over desired 24,000 gph.—*H. E. Babbitt*

A Rural Water Supply Scheme [Gt. Br.]. R. W. HAWKEY. Wtr. & Wtr. Eng. (Br.), **56**:339 ('52). Docking Rural Dist. of Norfolk, with 30 parishes, totaling 87,386 acres, is one of driest areas in Britain. In '45 council prepared scheme for all villages in rural dist. It involves one 18" borehole to depth of 175' capable of yielding 31,000 gph (Imp.) and second borehole, close to first, to depth of 165'. Future demand estd. at 25 gpcd for domestic use, and 7.5 gpcd for agricultural use. New pumping station has been constructed over boreholes from which water is pumped to new reservoir and water tower. Mains have been laid so that water is within easy reach of about 99% of pop. Pumping station is designed to supply 340,000 gpd, and reservoir and water tower provide storage for about 2 days' demand. Each pumping unit consists of 4-stage borehole pump with approx. 54' of shaft, driven by 51-hp vertical a-c motor at pumphouse floor level. Each pump will deliver 17,100 gph against total head of 317.5'. Concrete reservoir has 400,000-gal capac., and water tower 225,000-gal capac. Mains consist of 3"–12" spun-iron pipes and have flexible screwed-gland spigot and socket joints.—*H. E. Babbitt*

Stanion Lane Filter Station, 1949 [Gt. Br.]. G. C. S. OLIVER. J. Inst. Wtr. Engrs. (Br.), **6**:196 ('52). Filter plant consists of dry chem. storage bldg., coagulation and flocculation tanks, 4 rapid sand gravity filters to run at 2 gpm (Imp.)/sq ft, one 100,000-gal filtered-water underground tank, and pumps. After 6 mo. operation in '42, sand was covered with black mud wrapped around sand grains. Substance contained 72.4% alum and chalk and 27.6% organic matter. Removal of layer of this substance had no effect on filter runs. Tastes appeared toward end of '43. Chem. dosages were increased as follows: alum, 42 to 49 ppm; chalk, 7 ppm; and activated carbon, 7 ppm, with attempt to reduce turbidity from 3 to 1 ppm. Filter runs quickly deteriorated and mud accumulated alarmingly. Mud was scraped off weekly with addn. of clean makeup sand. Despite this, mudballs developed below sand surface. Air agitation failed to come through in many places. Meanwhile several remedial measures were being taken. Sand was removed from filter and cleaned by scrubbing in trough with water agitation. Lab. tests showed that however much sand was washed it would have to be chemically treated, and this could be done with chlorine and caustic soda. After filter was taken out of service, water was drawn down to 2" over filter surface, 20 ppm chlorine was added, and filter was agitated with air and allowed to stand 3 days. 5% soln. of caustic soda was added, and hourly agitation with air was tried for 8 hr. Filter was repeatedly washed thereafter in ordinary way until caustic soda had been removed. Foot of medium was then removed and further doses of chlorine and caustic soda applied. In autumn of '43 filtered water had distinct taste and smell, and turbidity rose to well over 3 ppm. Wash water rose to 50%. Prechlorination was

(Continued on page 78)

Here are the answers on CARLON Plastic Pipe
WORKING PRESSURES AND TEMPERA-
PLICATIONS FOR CARLON?
Actually, Carlon pipe can be used in any ap-
plication where the temperatures do not ex-
ceed 140°F. and where working pressures do
not exceed those established for each size. See
chemical resistance charts for further data.
CAN CARLON PIPE BE USED FOR
THAN LIQUIDS?
12. IS THERE A
BRANDS OF PLASTIC PIPE?
Yes. Because Carlon, as the largest producer
of plastic pipe, continues to lead in the de-
velopment and research of plastic pipe as well
as technological "know-how", they are better
prepared to serve your piping needs today
through utilization of exclusive production
techniques. While most plastic pipes are made
from similar materials, it is the scientific com-
pounding of these materials that makes Carlon
. . . the first real pipe that is plastic.
14. WHAT DIFFERENT TYPES OF CAR-
LON FLEXIBLE PIPE ARE AVAILABLE?
Carlon "EF" (white stripe) is the most com-
monly used pipe for the handling of drinking
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sumption. Carlon "WP" pipe (green stripe) is
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pressures are involved in the handling of
31. IS CARLON
Yes. Only Carlon pipe
assured forever against
lytic corrosion as well as
and workmanship.
22. WHY IS CARLON P
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proper type of pipe for your
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is guaranteed!
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(Continued from page 76)

adopted at end of '43 and conditions improved during first half of '44. In spring of '45 there was heavy diatom growth in reservoir which prevented high alum dosage. Early in '44 it had become evident that drastic alterations to plant were necessary. This involved installation of circular, vertical sedimentation tank with 4½-hr retention time at flow of 1 mgd (Imp.). At rising veloc. of 0.001 fps, floc was left at bottom of tank. Chlorination before sedimentation eliminated algal tastes. 3.5–7.0 ppm activated carbon was added after sedimentation but before filtration to eliminate earthy tastes.—*H. E. Babbitt*

The Water Supply of the Sindri Fertilizer Factory, Bihar, India. ANON. Wtr. & Wtr. Eng. (Br.), **56**:167 ('52). Sindri is small village on Damodar R. approx. 14 mi. downstream from Dhanbad. Works required for needed water supply consisted of barrage on Gowai R., tributary to Damodar R. approx. 4 mi. above Sindri, infiltration gallery to tap water available in sands in Damodar bed, and necessary riverside pumping and purification works. Construction of barrage has created lake impounding 0.8–1.0 bil gal (Imp.) of water. Catchment area above barrage is roughly 374 sq mi with max. discharge of approx. 70,000 cfs. Dam is 930′ between abutments, divided into 26 spans, each of 30′. Central 14 spans have steel lift gates. Works were opened on Nov. 7, '51. Pumping station and infiltration gallery were completed in June '51. Final units of filtration plant were put into operation in Nov. '51. Water for both boiler and process use is softened in cold-lime softening plant and clarified using sodium aluminate. Paterson type clarification plant is designed to handle 7,000 gpm (Imp.). Softening and clarification are effected in "Accelator" plant, giving water with turbidity of 10 ppm or less. Feed to boilers consists of return condensate and makeup from clarification plant. Feedwater heating and treatment systems consist of four groups: [1] hot-process softener; [2] deaerators; [3] feedwater supplementary treatment; and [4] closed feedwater heaters. For softening raw makeup water, Permutit type pressure lime softeners operating in parallel have been installed, each with capac. of 250,000 lb hourly. Separate Permutit combined deaerating heaters are provided for dealing with condensate, each with capac. of 250,000 lb hourly. High rate of makeup requires considerable boiler blowdown to keep total solids below 3,000 ppm. Because of undeveloped stage of Sindri area it has been necessary to construct large thermal powerhouse and to take elaborate measures to safeguard water supply.—*H. E. Babbitt*

Seasonal Variations of the Chemical Constituents in River Waters [Japan]. TAKAHISA HANYA & TADASHI OKABAYASHI. J. Chem. Soc. Japan, Pure Chem. Sec., **73**:97 ('52). Seasonal variations of chem. constituents of 6 rivers in Japan—Abukuma, Tone, Arakawa, Saikawa, Nagara, and Ota—discussed, 1935–1941 data used. Alky. increases in summer and decreases in winter. Cl ion increases in Jan., Feb., May, June, and July and decreases in Sept., Oct., and Nov. Sulfate decreases in Aug., Sept., and Oct. and increases in Dec., Jan., and Feb. Silicate increases in Jan., Feb., Sept., Oct., and Dec. and decreases in May and June. Consumption of $KMnO_4$ increases in Jan., Feb., and March and decreases in May, June, Aug., Sept., and Oct.—*CA*

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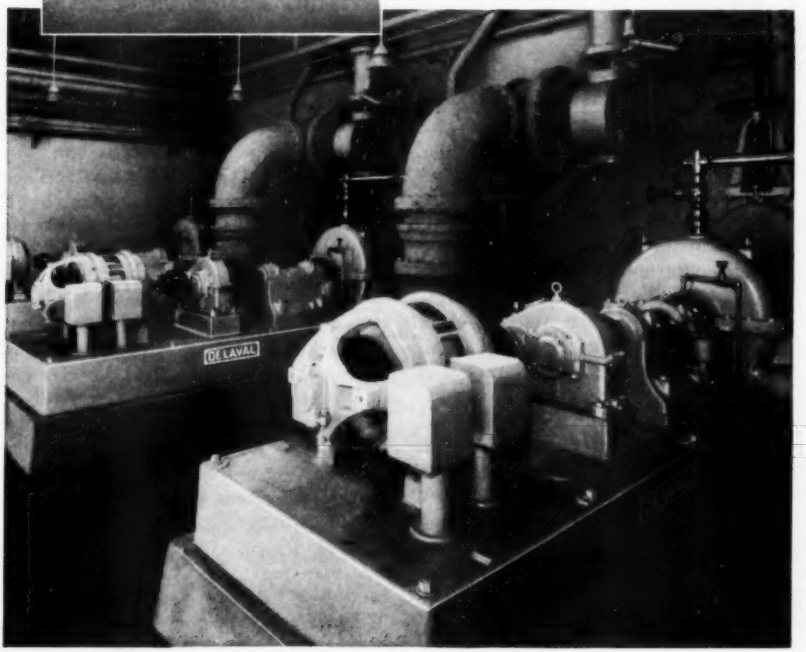

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Two of these high efficiency motor-driven horizontal pumps have a capacity of 3,000 gpm and the third a capacity of 7,000 gpm. Later, as flow increases, the two 3,000 gpm units can be replaced by a 7,000 gpm pump.

Slow speeds of these De Laval pumps insure long life, large passageways reduce clogging and nickel-chrome cast iron casings and impellers assure long wear.

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Section Meetings

California Section: The thirty-third annual conference of the California Section was held in Pasadena on October 28–31, with headquarters at the Huntington Hotel. Chairman Joseph D. DeCosta presided. The registration of 1,434 was a new record for the section.

The technical sessions began on Wednesday afternoon with a paper on "Forty Years Developing a Water System" by Duncan Blackburn, assistant chief engineer of the Pasadena Water Dept. A paper on "Accident Prevention" was presented by Merle Jackson, safety engineer for the State Div. of Industrial Safety. Three papers were presented on water system records: "Distribution System Records" by Frank E. Alderman, consulting engineer; "Production and Supply Records" by Marvin H. Owen, senior mechanical engineer, Los Angeles Dept. of Water and Power; and "Importance of Records to Management" by Everett L. Clark, consulting engineer.

On Thursday the three divisions held parallel sessions under the chairmanship of the division chairmen. The Business Management Division session was conducted by Philip F. Walsh, the Water Supply and Distribution Division session by M. J. Shelton, and the Water Purification Division by Blair I. Burnson.

The general session on Friday began with a paper on "Coatings for Steel Water Pipe" by Walter H. Cates, manager, Hydraulic Div., Consolidated Western Steel Co. R. C. Kennedy, chief engineer for the East Bay Municipal Utility Dist. presented a paper on the district's experience and methods in protecting steel pipe with cement-mortar linings and coatings. Robert B. Diemer, general manager and chief engineer of the Metropolitan Water Dist. of Southern California reviewed the "Expansion of the Colorado River Aqueduct System."

A paper on "Cloud Physics, Its Theory and Application" was presented by Eugene Bollay of North American Weather Consultants, Pasadena. President Charles H. Capen reviewed the probable water development in the future. "NPA Controls and the Future" was the subject of a paper presented by E. T. Sharp, superintendent of stores for Los Angeles Dept. of Water and Power. A paper on "What Are We Doing to Improve Our Water Supply in San Diego County" was presented by James P. Slater, chief, Div. of Sanitation, Dept. of Public Health, San Diego County.

A M Rawn, chief engineer and general manager of the Los Angeles County Sanitation Dist., presented a paper on "Integrating Reclamation and Disposal of Waste Water." The "California Civil Defense Plans" were reviewed by Samuel B. Nelson, member of the Governor's Utility Advisory Committee on Civil Defense, and assistant chief engineer of water works, Los Angeles. He emphasized that under the plan the water utilities would, during an emergency, be directed by regional water operating engineers who report to and receive orders from a state water operating engineer. Liaison is maintained with the Regional Civil Defense office through a water service chief.

The Executive Committee of the Section met on Thursday morning to transact business and receive the reports from committees and divisions. A complete report rendered by the Fluoridation Com-

(*Continued on page 82*)

This water line hurries with 50-foot steps

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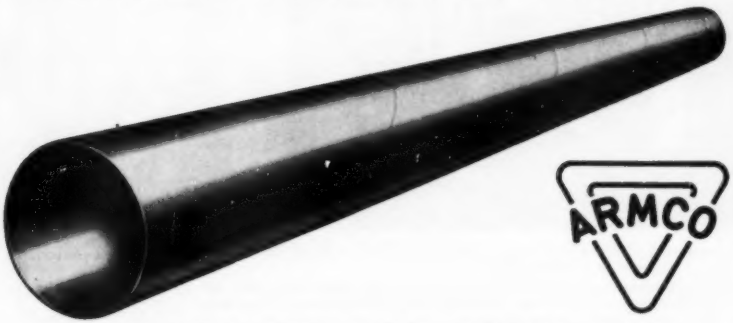

ARMCO

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Meets A. W. W. A. Specifications

Section Meetings

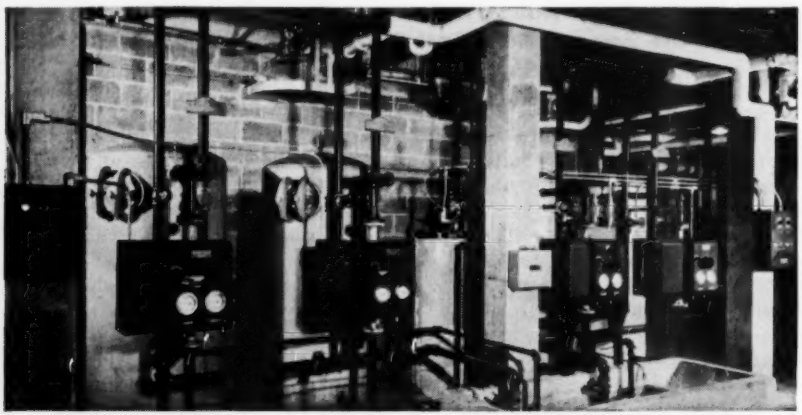
(Continued from page 80)

mittee under the chairmanship of H. Christopher Medbery is to be sent out to the members of the section. The Convention Location Committee for 1954 selected Monterey for the Spring meeting and Long Beach for the regular conference. There was a discussion on the manufacturers association financial participation in the section meeting and it was decided that the Friday night banquet sponsored by the manufacturers with all AWWA members and their wives registered at the convention eligible for free tickets was a satisfactory type of participation. Discussions on utility costs in the relocation of facilities in highway construction and the new AWWA Research Committee were placed on the agenda for the spring meeting. A resolution supporting California's stand in the Colorado River controversy was passed.

The general business meeting was held on Friday afternoon. The divisions reported the election of the following chairmen: Business Management, John W. McFarland, Oakland; Water Supply and Distribution, Carl A. Lauenstein, San Francisco; and Water Purification, Lee Streicher, La Verne. The newly elected officers for the section were: chairman, Laurance E. Goit, Los Angeles; vice-chairman, H. Christopher Medbery, San Francisco; and the new members to the Executive Committee were: Kenneth W. Brown, San Francisco; Robert B. Diemer, Los Angeles; Leslie A. Hosegood, San Bernardino; and Frank M. Brooks, Pasadena. Chairman DeCosta reported that Morris Jones had resigned as national director and Lauren W. Grayson had been appointed to complete the term.

On Wednesday night the "All Divisions Dinner" was held in the Huntington Hotel with Chairman DeCosta as

(Continued on page 84)



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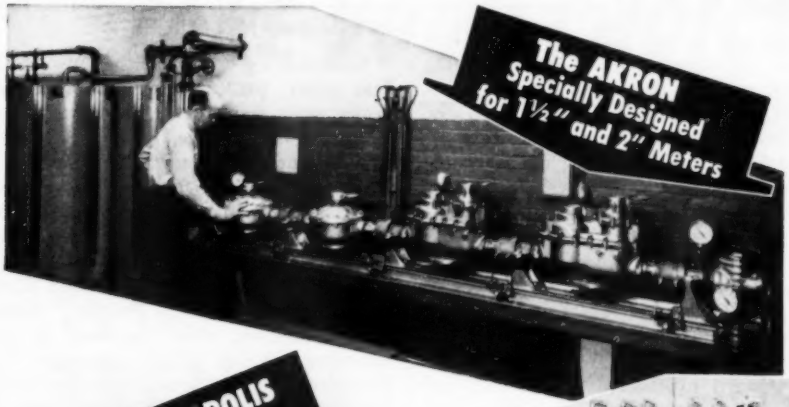

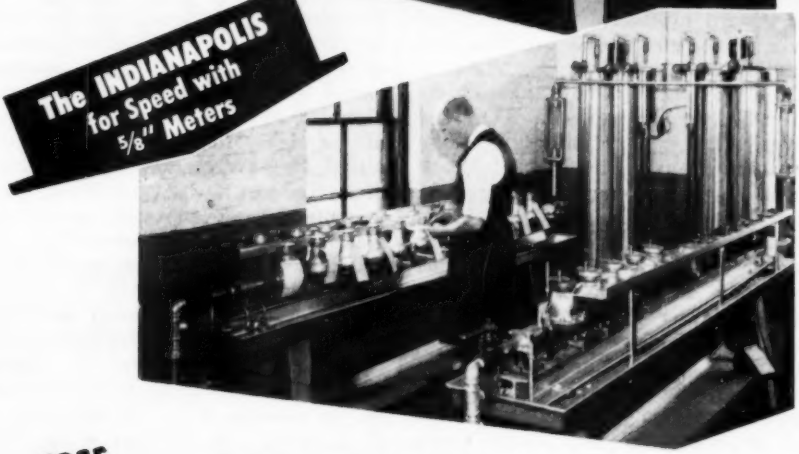

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Section Meetings

(Continued from page 82)

master of ceremonies. The principal speaker was W. Ballentine Henley, member of the Los Angeles Board of Water and Power Commissioners, who gave an inspirational talk on the place and importance of the water works industry. President Charles H. Capen gave greetings from the national office and presented Life Membership certificates to Carroll B. Abbott, Melvin L. Enger, Ingwald E. Flaa, and Fred J. Klaus. Burton S. Grant presented the Fuller Award nomination to John S. Longwell and the Elliott Award to Walter H. Cates. The prizes for the golf tournament were presented by Claude T. Faw.

On Friday night all those attending the convention were guests of the Water and Sewage Works Manufacturers Association at the annual banquet. J. H. Peterson was master of ceremonies and the entertainment was arranged for by K. A. Keirn.

Luncheon on Thursday was held on the Huntington Hotel Pool Terrace where the 1952 Water Works Aquacade was held. Women's entertainment included a play review by Edna Steams Dayton on Wednesday, a suggested visit to the Pasadena Playhouse on Thursday night and a trip on Friday to the Forest Lawn Memorial Park.

J. C. LUTHIN
Secretary-Treasurer

Virginia Section: The Virginia Section held its nineteenth annual meeting at the Chamberlin Hotel in Old Point Comfort on November 5–7, 1952. A total of 237 members and guests were registered, establishing a new attendance record.

Wednesday morning, November 5, was devoted to registration and committee meetings. Preliminaries at the opening session Wednesday afternoon were presided over by Chairman Bryant L. Strother, who welcomed the group and urged their participation in the discussion of subjects presented.

"Selection, Positioning and Servicing of Chemical Feeders" was the topic of the first paper, presented by Rollie J. Leveque, sales manager of the Omega Machine Co., Providence, R.I. G. R. Talcott, engineer of the firm of R. Stuart Royer & Assoc., Richmond, led an open discussion on the subject. The next scheduled presentation was entitled "Water Works Picture," a word and picture description of the water supplies at Alexandria, Norfolk, and Newport News. E. H. Aldrich, chief engineer of the American Water Works Service Co., Philadelphia, described Alexandria's new filtration plant. W. G. Beasley, chemist of the Div. of Water Supply, Norfolk, gave a historical sketch of the growth of Norfolk's water system and showed slides of the new Moores Bridges filtration plant. M. G. Welsh, mechanical engineer of the Newport News Water Works Com., presented a most interesting story of the Newport News system which has over 700 miles of mains serving the Peninsula area.

The first scheduled paper of the Thursday morning session, "New Alloys and Materials of Construction for Special Chemicals," was read by Michael Monack in the absence of L. R. Honnaker of E. I. du Pont de Nemours & Co., Wilmington, Del., the author of the paper. Executive Asst. Secy. Raymond J. Faust of AWWA discussed "The Application of a Safety Program to the Water Works Industry" (see January issue, p. 19). The final morning session included a panel on "Billing and Collection Problems," led by R. D. Wright, director of the Lynchburg Water Dept. H. B. Rice, city manager of Williamsburg; Seth Burnley, city manager of Staunton, and Wallace White of the Dept. of Public Utilities, Richmond, participated.

The first paper on Friday morning was entitled "Pollution Abatement and Raw Water Quality" by A. H. Paessler, executive secretary of the State Water Control Board, Richmond. The second presentation was a paper by Fred E. Stuart,

(Continued on page 86)

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(*Continued from page 84*)

president of Stuart Corp., Baltimore, Md., on "Coagulation and Its Effect on Fluoridation." The final session of the meeting was a panel discussion on "Distribution System—Maintenance, Repairs, and Practices." The panel was led by Whitworth Cotton, city engineer of Petersburg, and included J. B. Ferguson, superintendent, Roanoke Water Dept., R. L. Maury, director, Public Works, Martinsville, and T. W. Edwards, city engineer, Charlottesville.

On Thursday afternoon the group was taken on a sightseeing tour of the Hampton Roads Harbor. The local arrangements committee arranged for the boat trip with the U.S. Coast Guard, which made available its large Coast Guard vessel "The Chincoteague."

Entertainment features in addition to the boat trip included a floor show and dance on Thursday night. The ladies were entertained on Wednesday afternoon at the Jefferson Davis Case-Mate and on Thursday morning there was a session of bridge and other card games.

The annual banquet was held on Thursday night and "Old Dominion Citation" awards were presented to Richard Wagner and A. W. Lamond. Life Membership Certificates in AWWA were presented to Richard Messer, Bob Bardwell, Richard Wagner, Louis Geupel, and C. W. Smedberg. C. E. Moore announced that by unanimous choice the Fuller Award Committee had selected M. J. "Mike" Siebert as nominee.

W. H. SHEWBRIDGE
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An all-purpose centrifugal pump that can move up to 500 gpm, or handle heads up to 135 ft, is described in a folder, Bul. 52B6691A, on frame-type centrifugal pumps offered by Allis-Chalmers Mfg. Co., 1026 S. 70th St., Milwaukee, Wis. Head and capacity can be changed by changing the sheave size on the **V**-belt drive.

An "Industrial Waste Treatment Guide" has been issued by B-I-F Industries, 345 Harris Ave., Providence 1, R.I., as B-I-F Bul. 4. It describes types and combinations of treatment that are applicable to various industrial waste products.

A construction data handbook has been issued by A. C. Horn Co., 10th St. & 44th Ave., Long Island City 1, N.Y., manufacturers of building maintenance and construction materials. The 106-p. booklet includes tables of dimensional and other reference data useful in masonry work and the surfacing of buildings, and catalog information on cements, caulking compounds, and various paints and coatings.

(*Continued on page 88*)

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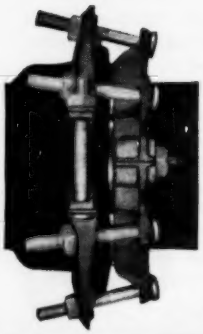

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(*Continued from page 86*)

"Hot Water Temperature Control" is the subject of a circular distributed by Water Service Labs., Inc., 423 W. 126th St., New York 27, N.Y. The supply of hot water to large but individual buildings (such as apartment houses) is discussed, tracing each of half a dozen usual methods.

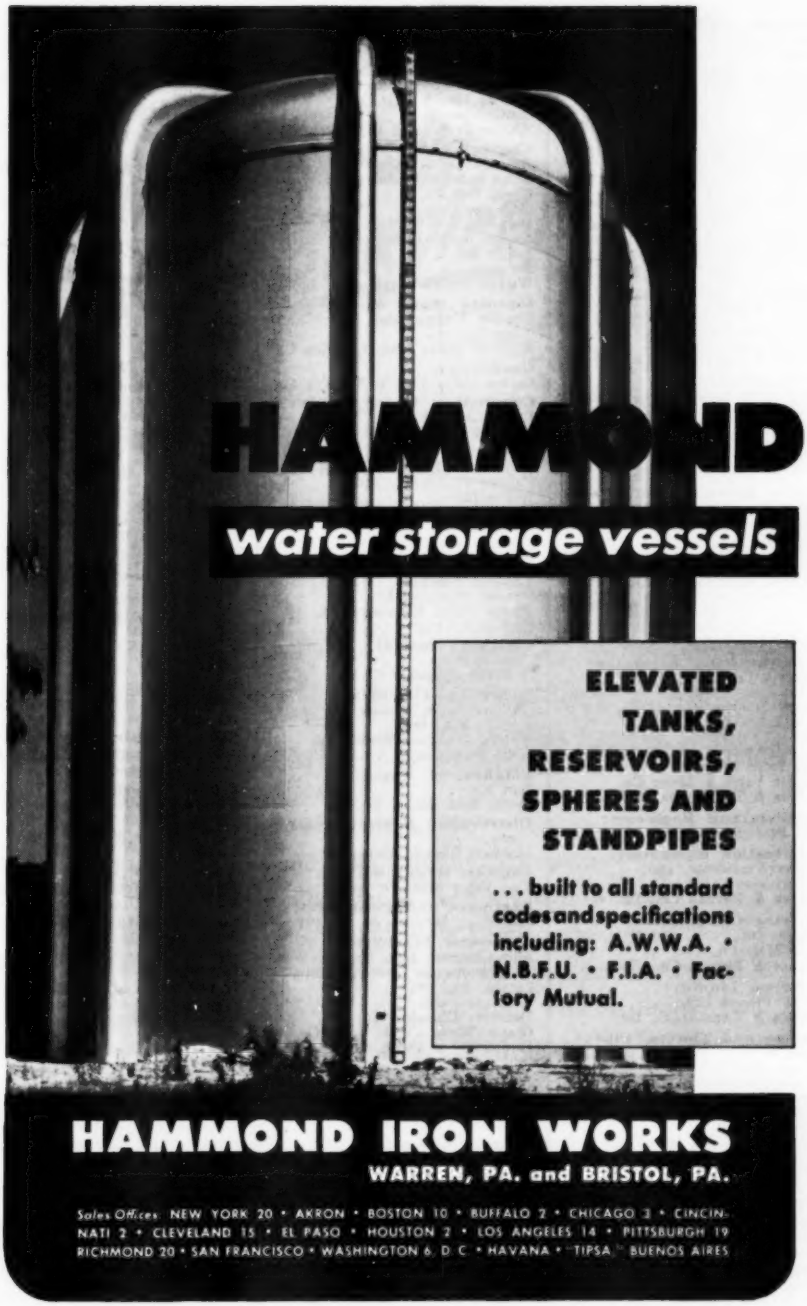
An X-ray spectrographic chart for elements from sodium to uranium (atomic numbers 11-92) is being offered by the Research & Control Instruments Div., North American Philips Co., 750 S. Fulton Ave., Mt. Vernon, N.Y. The chart is approximately 17 by 22 in., and suitable for wall display.

A pocket calendar and data card of plastic is being distributed by Armco Drainage & Metal Products, Inc., Middletown, Ohio. Included, besides the 1953 calendar and the Armco name, are a sheet steel gage table, circular area equivalents, and other data.

The microfilming services offered by Remington Rand Inc., 315—4th Ave., New York 10, are described in an 8-p. booklet just issued. The types of film available and the procedure to be followed in transferring records to film are depicted.

Fluoridators are described in an illustrated folder distributed by Wallace & Tiernan Co., Box 178, Newark 1, N.J. Solution-feed, volumetric and gravimetric models are offered.

Interlocked, diecut reference cards are shown and their applications to commercial uses described in an 8-p. booklet on the Remington Rand Chaindex system. Copies of the bulletin, which is known as KD 574, may be obtained from Remington Rand Inc., 315—4th Ave., New York 10, N.Y. The cards come in a variety of sizes and overlapping exposures and may be fed into a typewriter singly or in linked groups.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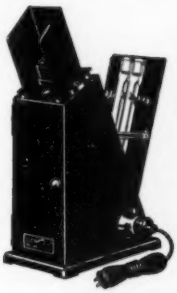

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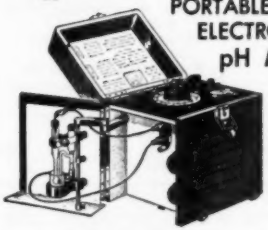

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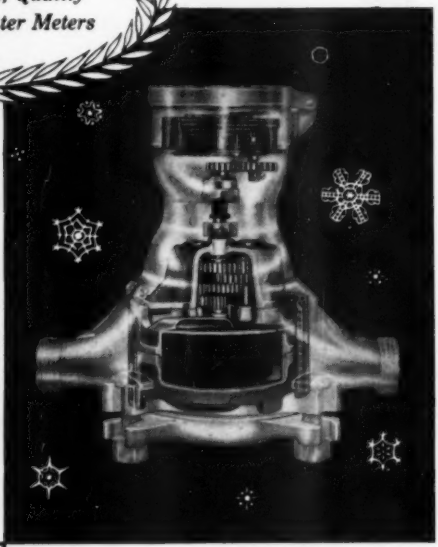
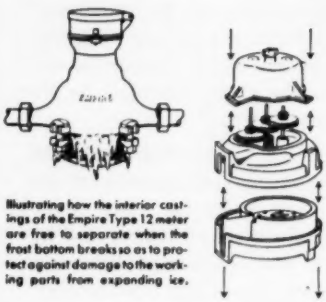
INTERNALLY



HERE'S HOW IT WORKS



Illustrating how the interior castings of the Empire Type 12 meter are free to separate when the frost bottom breaks so as to protect against damage to the working parts from expanding ice.

WHEN METER FREEZES . . .

ALL PARTS SEPARATE

In all other meter designs the interior parts are bolted together and, in some, the interior assembly is directly attached to the meter casing at the stuffing box.

In the Empire Type 12 meter *alone*, the interior castings are jointed and held together without the use of screws or bolts. Thus, when an Empire meter freezes, the bottom plate breaks and the parts all come apart. They are then free to move with the expanding ice and are thus protected against strain or distortion. This money saving feature of Empire Type 12 meters is fully described in bulletin W-802. Write for your copy today.

. . . and the EMPIRE TYPE 14

AN ALL-BRONZE METER FOR WARM CLIMATES

Especially designed for use below the frost belt. All-bronze construction presents many advantages including ability to combat electrolytic action. Exclusive design using oscillating piston principle has fewer working parts than any other meter. Described in bulletin W-801.

ROCKWELL MANUFACTURING COMPANY

PITTSBURGH 8, PA. Atlanta Boston Chicago Houston Kansas City
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At Dallas, Texas...

Softening and Coagulation

calls for conventional treatment

Just like your fingerprints . . . no two water treatment problems are exactly alike. The answer to your specific problem must be determined by an analysis of raw water composition, rate of flow and other variables. In Dallas, these factors add up to conventional treatment with Dorr equipment.

Whether your problem requires high-rate or conventional types of units, call Dorr for equipment recommendations to give you the end result you want. Under all types of conditions, throughout the world, Dorr installations are providing positive sludge removal . . . with minimum water loss.

Interesting information about many types of Dorr water treatment equipment is in Bulletin No. 9141. Ask us to send you a copy. THE DORR COMPANY, Stamford, Conn.

Every day, nearly 8 billion gallons of water are treated by Dorr equipment.

The Elm Fork water treatment plant at Dallas, Texas, treats an average flow of 64 M.G.D., while maximum capacity is 96 M.G.D. This plant uses the following Dorr equipment: **8** Dorrco Primary Flash Mixers, **4** Dorrco Secondary Flash Mixers, **2** Dorrco Primary Flocculators*, **2** Dorrco Secondary Flocculators and **4** Dorrco Squarex* Crossflow Clarifiers (each 160′ square). * Reg. U. S. Pat. Off.

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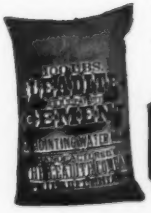
Jointed for . . . Permanence with LEADITE

Generally speaking, most Water Mains are buried beneath the Earth's surface, to be forgotten,—they are to a large extent, laid for permanency. Not only must the pipe itself be dependable and long lived,—but the joints also must be tight, flexible, and long lived,—else leaky joints are apt to cause the great expense of digging up well-paved streets, beautiful parks and estates, etc.

Thus the "jointing material" used for bell and spigot Water Mains MUST BE GOOD,—MUST BE DEPENDABLE,—and that is just why so many Engineers, Water Works Men and Contractors aim to PLAY ABSOLUTELY SAFE, by specifying and using LEADITE.

Time has proven that LEADITE not only makes a tight durable joint,—but that it improves with age.

The pioneer self-caulking material for c. i. pipe.
Tested and used for over 40 years.
Saves at least 75%



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No Caulking